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UPPER CRETACEOUS FLORAS OF THE EASTERN GULF REGION IN TENNESSEE, MISSISSIPPI, ALABAMA, AND GEORGIA

BY

EDWARD WILBER BERRY

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CONTENTS.

Page.

- Introduction 7
- General relations of the Cretaceous deposits 7
- Tuscaloosa formation 11
    - Historical sketch 11
    - Areal distribution 12
    - Lithologic character 12
    - Stratigraphic relations 14
    - Local sections containing plant remains 14
        - Near Iuka, Miss 14
        - Glen Allen, Ala 14
        - Shirleys Mill, Ala 16
        - Tuscaloosa, Ala 17
        - Cottondale, Ala 18
        - Snow plantation, near Tuscaloosa, Ala 19
        - Sanders Ferry Bluff, Ala 20
        - Whites Bluff, Ala 21
    - Composition, origin, and evolution of the Tuscaloosa flora 22
    - Ecologic conditions indicated by the Tuscaloosa flora 26
- Eutaw formation 30
    - Historical sketch 30
    - Areal distribution 31
    - Lithologic character 31
    - Stratigraphic relations 31
    - Local sections containing plant remains 32
        - McBrides Ford, Ga 32
        - Broken Arrow Bend, Ga 32
        - Chimney Bluff, Ga 32
        - Havana, Ala 33
        - Coffee Bluff, Tenn 33
    - Composition and ecologic conditions indicated by the Eutaw flora 35
- Selma chalk 36
- Ripley formation 37
    - Historical sketch 37
    - Areal distribution 37
    - Lithologic character 37
    - Stratigraphic relations 37
    - Plant localities 37
- Bearing of the floras on correlation 39
    - Correlation of the Tuscaloosa flora 39
    - Correlation of the Eutaw flora 41
    - Correlation of the Ripley flora 42
- Distribution of the Tuscaloosa, Eutaw, and Ripley floras 43

Page.

- The floras 49
    - Phylum Thallophyta 49
        - Class Fungi 49
            - Order Pyrenomycetes 49
    - Phylum Bryophyta 49
        - Class Hepaticae 49
            - Order Jungermanniales 49
    - Phylum Pteridophyta 49
        - Order Equisetales 49
        - Order Lycopodiales 50
        - Order Filicales 51
    - Phylum Spermatophyta 55
        - Class Gymnospermae 55
            - Order Cycadales (?) 55
            - Order Coniferales 56
        - Class Angiospermae 70
            - Subclass Monocotyledonae 70
                - Order Liliales 70
                - Order Graminales 71
                - Order Arecales 72
            - Subclass Dicotyledonae 72
                - Order Piperales 72
                - Order Juglandales 73
                - Order Myricales 73
                - Order Fagales 75
                - Order Salicales 75
                - Order Urticales 78
                - Order Platanales 83
                - Order Proteales 85
                - Order Ranales 86
                - Order Papaverales 95
                - Order Rosales 96
                - Order Geraniales 104
                - Order Sapindales 106
                - Order Rhamnales 112
                - Order Malvales 116
                - Order Thymeleales 118
                - Order Myrtales 125
                - Order Umbellales 128
                - Order Ericales (?) 130
                - Order Primulales 133
                - Order Ebenales 134
                - Order Gentianales 136
                - Order Polemoniales 137
                - Position uncertain 137
- Index 173

ILLUSTRATIONS.

		Page.
PLATE	I. Map showing the areal distribution of the Upper Cretaceous deposits of the eastern Gulf region	8
	II. *A*, Cut in the Tuscaloosa formation near Glen Allen, Ala., along the St. Louis-San Francisco Railway, showing sands below the ferruginous ledge and leaf-bearing clays above; *B*, Whites Bluff, Black Warrior River, Ala., showing sands and leaf-bearing clays of the Tuscaloosa formation	14
	III. *A*, Roadside wash in the Tuscaloosa formation near Shirleys Mill, Ala., exposing highly fossiliferous clays; *B*, View showing basal gravel overlain by laminated clays, of the Tuscaloosa formation, bearing leaves, lignite, and amber, 1⅝ miles east of Iuka, Miss	16
	IV. *A*, View showing the argillaceous leaf-bearing sands of the Ripley formation, 13 miles northwest of Camden, Tenn; *B*, View showing the character of the bedding of the basal sands and clays of the Eutaw formation, 2 miles southeast of Havana, Ala	32
	V-XXXIII. Fossil plants from the Upper Cretaceous formations	143
FIGURE	1. Section of the Tuscaloosa formation in an exposure at Glen Allen, Fayette County, Ala	15
	2. Section of the Tuscaloosa formation in an exposure near Shirleys Mill, 10 miles southeast of Fayette, Fayette County, Ala	16
	3. Section of the Tuscaloosa formation in an exposure near Cottondale, Tuscaloosa County, Ala	18
	4. Section of the Tuscaloosa formation in an exposure in a gully on the Snow plantation, 9 miles southwest of Tuscaloosa, Ala	19
	5. Section of the Tuscaloosa formation in an exposure at Sanders Ferry Bluff, on Black Warrior River, 12 miles below Tuscaloosa, Ala	21
	6. Section of the Tuscaloosa formation in an exposure at Whites Bluff, Black Warrior River, 52¾ miles below Tuscaloosa, Ala	22
	7. Sketch map showing the Tuscaloosa drainage and its subsequent history	27
	8. Hypothetical section illustrating the interrelationship of the Upper Cretaceous types of sedimentation from Tuscaloosa to lower Selma	28
	9. Section of Eutaw formation exposed in one of the deep gullies 2 miles southeast of Havana, Hale County, Ala	34
	10. Diagrammatic section of the Ripley formation in McNairy County, Tenn., from northeast to southwest	39
	11. Restoration of *Dewalquea smithi*	87
	12. Restoration of *Bauhinia alabamensis*	99

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UPPER CRETACEOUS FLORAS OF THE EASTERN GULF REGION IN TENNESSEE, MISSISSIPPI, ALABAMA, AND GEORGIA.

By Edward Wilber Berry.

INTRODUCTION.

The eastern Gulf region discussed in this paper includes that part of the Atlantic Coastal Plain bordering on the Gulf of Mexico and lying south and west of the southern Appalachian province and east of Mississippi River. The area of outcrop of the Upper Cretaceous deposits borders the inland margin of the Coastal Plain (see Pl. I), and the belt from which determinable plant fossils have been collected extends from Benton County, in west-central Tennessee, southward and eastward to west-central Georgia. Most of the fossil plants come from the basal formation of the Upper Cretaceous series—the Tuscaloosa formation.

The overlying Eutaw, Selma, and Ripley formations, with their various members, are marine deposits with abundant molluscan faunas, which do not fall within the scope of the present contribution. A few fossil plants have been found in the basal beds of the Eutaw formation in Tennessee, Alabama, and Georgia, in the upper beds of the Eutaw formation in Tennessee, and a still smaller and more poorly preserved representation occurs in the shallow-water phases of the Ripley formation in Tennessee, eastern Alabama, and western Georgia.

As the bulk of the flora is from the Tuscaloosa formation and the representation of the Eutaw and Ripley floras is too meager to throw any considerable light upon their correlation or the physical conditions accompanying deposition, this contribution will be devoted principally to the elucidation of the Tuscaloosa flora and should be regarded simply as a preliminary report, for though it exhausts the present extensive collections, it should be remembered that both my own geologic work and that of my associates in this vast area was of a reconnaissance nature only. Later, when the abundant workable clays of the Tuscaloosa formation are developed for economic purposes many new localities will probably be discovered and it may be possible to recover additional representatives of the flora.

GENERAL RELATIONS OF THE CRETACEOUS DEPOSITS.

Both Lower and Upper Cretaceous deposits are represented in the eastern Gulf area, but the former are much less extensive and varied than in the middle Atlantic slope to the northeast or in the western Gulf area to the west in Texas and Mexico.

Lower Cretaceous sediments are present only in the eastern part of the area, where the southwesterly extension of the Potomac group of the Middle Atlantic States crosses Georgia along the fall line as an irregular belt of unfossiliferous cross-bedded arkosic sandy clays and light-colored kaolins 5 to 30 miles wide, extending westward into Alabama as a belt 4 to 8 miles wide that terminates in Elmore County.

The Upper Cretaceous is subdivided into the Tuscaloosa formation, the Eutaw formation, the Selma chalk, and the Ripley formation.

The Tuscaloosa is the basal formation of the eastern Gulf Coastal Plain from Elmore County, Ala., to Tishomingo County, Miss., where it gradually thins and is transgressed by the overlying Eutaw formation. The Tuscaloosa doubtless impinges on the Lower Cretaceous at the former's easternmost development, but both the Tuscaloosa and the Lower Cretaceous have been transgressed by the Eutaw and the details are obscured.

The Eutaw forms a belt of varying composition (sands, clays, and marls) extending from Taylor County, in western Georgia, to the southern part of Benton County, in western Tennessee, and as isolated remnants as far north as Trigg County, Ky. In Georgia and eastern Alabama it rests with a marked unconformity on the Lower Cretaceous. Throughout the rest of Alabama it overlies the Tuscaloosa without apparent unconformity. Beyond the Tuscaloosa region in Tennessee, where it is represented by the Coffee sand member, the Eutaw constitutes the basal formation of the Coastal Plain, resting on the rocks of the Paleozoic floor, except where remnants of the Tuscaloosa are preserved.

The Selma chalk is a lithologic and not a chronologic unit, as it includes in the area of its greatest development equivalents of parts of the Eutaw and Ripley, as those formations are developed elsewhere. It extends from east-central Alabama to southern Benton County, Tenn., resting throughout without apparent unconformity on the Eutaw.

The deposits of the Ripley sea extend from Twiggs County, in central Georgia, to the head of the Mississippi embayment in southern Illinois and probably westward through the western Gulf region, although there is a wide interval in Missouri and Arkansas that was transgressed by Eocene deposits, large areas of which were subsequently removed by the action of Mississippi River during late Tertiary and Quaternary time.

These deposits of the Ripley sea do not constitute a single lithologic or formational unit, because in the eastern Gulf region those in the Chattahoochee basin are separated from those in northeastern Mississippi and the States northward by the western Alabama area, in which the Selma chalk continues to the top of the Upper Cretaceous.

The following list is a systematic arrangement of the plants found in the Upper Cretaceous of the Gulf region. In this list the species from the Tuscaloosa are denoted by the letter "T," and those from the Eutaw and Ripley by "E" and "R," respectively.

PHYLUM THALLOPHYTA.

Class Fungi.

Order Pyrenomycetes.

Sphaerites alabamensis Berry. T.

Class Algae (?).

Halymenites major Lesquereux. E, R.

PHYLUM BRYOPHYTA.

Class Hepaticae.

Order Jungermanniales.

Jungermannites cretaceus Berry. T.

PHYLUM PTERIDOPHYTA.

Order Equisetales.

Equisetum? sp. Berry. T.

Order Lycopodiales.

Lycopodium cretaceum Berry? T.
Lycopodites tuscaloosensis Berry. T.

Order Filicales.

Family Polypodiaceae.

Cladophlebis alabamensis Berry. T.
Dryopterites stephensoni Berry. T, R.
Asplenium dicksonianum Heer. T.

Family Cyatheaceae.

Dicksonia groenlandica Heer. T.

Family Gleicheniaceae.

Gleichenia delicatula Heer. T.

Family Marattiaceae (?).

Marattia cretacea Velenovsky? T.

PHYLUM SPERMATOPHYTA.

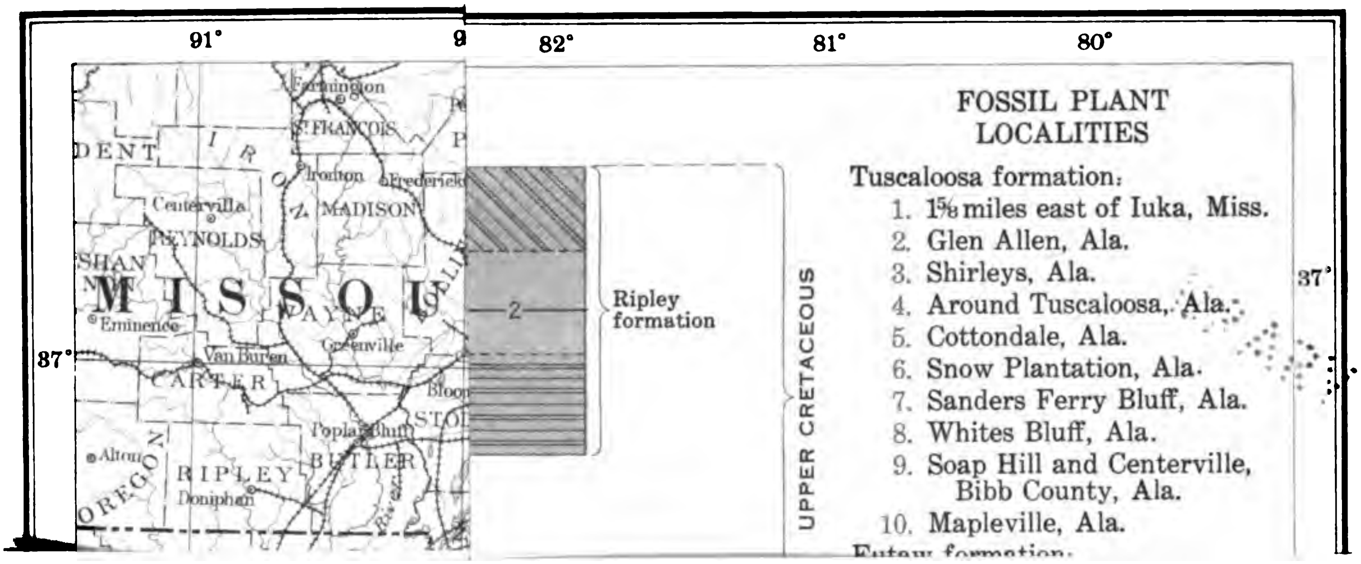
Class Gymnospermae.

Order Cycadales (?).

Podozamites marginatus Heer. T.
Cycadinocarpus circularis Newberry. T.

Order Coniferales.

Cephalotaxospermum carolinianum Berry. E.
Protophyllocladus subintegrifolius (Lesquereux) Berry. T.
Cunninghamites elegans (Corda) Endlicher. R.
Brachyphyllum macrocarpum formosum Berry. T, E.
Dammara borealis Heer. T.
Protodammara speciosa Hollick and Jeffrey. T.
Geinitzia formosa Heer. T.
Araucaria bladenensis Berry. E, R.
    jeffreyi Berry. E, R.
Androvettia carolinensis Berry. T.
    elegans Berry. E.
Abietites foliosus (Fontaine) Berry. T.
Sequoia reichenbachi (Geinitz) Heer. T, E.
    heterophylla Velenovsky. T.
    ambigua Heer. T, E.
    fastigiata (Sternberg) Heer. T.
Widdringtonites subtilis Heer. T.
    reichii (Ettingshausen) Heer. T.
Pinus raritanensis Berry. T.
Tumion carolinianum Berry? E.
Cupressinoxylon sp. E.



FOSSIL PLANT LOCALITIES

Tuscaloosa formation:
1. 1⅝ miles east of Iuka, Miss.
2. Glen Allen, Ala.
3. Shirleys, Ala.
4. Around Tuscaloosa, Ala.
5. Cottondale, Ala.
6. Snow Plantation, Ala.
7. Sanders Ferry Bluff, Ala.
8. Whites Bluff, Ala.
9. Soap Hill and Centerville, Bibb County, Ala.
10. Mapleville, Ala.

Eutaw formation:

Class Angiospermae.

Subclass Monocotyledonae.

Order Liliales.

Doryanthites cretacea Berry. E, R.

Order Graminales.

Cyperacites sp. Hollick. T.
Phragmites prattii Berry. E.

Order Arecales.

Sabalites sp. Berry. R.

Subclass Dicotyledonae.

Order Piperales.

Family Piperaceae.

Piperites tuscaloosensis Berry. T.

Order Juglandales.

Family Juglandaceae.

Juglans arctica Heer. T, E.

Order Myricales.

Family Myricaceae.

Myrica emarginata Heer. T.
    longa (Heer) Heer. T.
    dakotensis minima Berry. T.
    ripleyensis Berry. R.

Order Fagales.

Family Fagaceae.

Dryophyllum gracile Debey. R.

Order Salicales.

Family Salicaceae.

Salix flexuosa Newberry. T, E.
    lesquereuxii Berry. T, E.
    eutawensis Berry. E.
    meekii Newberry. T.
Populus hyperborea Heer. T.
Populites tuscaloosensis Berry. T.

Order Urticales.

Family Moraceae.

Ficus krausiana Heer. T, E.
    crassipes (Heer) Heer. T, E.
    georgiana Berry. R.
    daphnogenoides (Heer) Berry. T.
    inaequalis Lesquereux. T.
    shirleyensis Berry. T.
    woolsoni Hollick. T.
    ovatifolia Berry. E.
    alabamensis Berry. T.
    fontainii Berry. T.

Order Platanales.

Family Platanaceae.

Platanus asperaeformis Berry. T.
    shirleyensis Berry. T.
    latior (Lesquereux) Knowlton. T.
    ripleyensis Berry. R.
    sp. Berry. R.

Order Proteales.

Family Proteaceae.

Proteoides conospermaefolia Berry. T.
Persoonia lesquereuxii Knowlton. T.
    lesquereuxii minor Berry. T.

Order Ranales.

Family Ranunculaceae (?).

Dewalquea smithi Berry. T.

Family Magnoliaceae.

Magnolia speciosa Heer. T.
    capellinii Heer. T, E.
    newberryi Berry. T.
    obtusata Heer. T.
    boulayana Lesquereux. T, E.
    longipes Hollick. T.
    lacoeana Lesquereux. T.
    hollicki Berry. T.
Liriodendron meekii Heer. T.

Family Menispermaceae.

Cocculus cinnamomeus Velenovsky (?) T.
    polycarpaefolius Berry. T.
    problematicus Berry. T.
Menispermites trilobatus Berry. T.
    integrifolius Berry. T.
    variabilis Berry. E.

Order Papaverales.

Family Capparidaceae.

Capparites cynophylloides Berry. T.
    orbiculatus Berry. T.

Order Rosales.

Family Mimosaceae.

Inga cretacea Lesquereux. T.

Family Caesalpiniaçeae.

Hymenaea fayettensis Berry. T.
Bauhinia cretacea Newberry. T, E.
    marylandica Berry. T.
    alabamensis Berry. E.
    ripleyensis Berry. R.
Palaeocassia laurinea Lesquereux. T.
Cassia vaughani Berry. T.

Family Papilionaceae.

Phaseolites formus Lesquereux. T
Colutea obovata Berry. T.
Liriodendropsis simplex (Newberry) Newberry. T.
angustifolia Newberry. T.
constricta (Ward) Hollick. T.

Leguminosae (position uncertain).

Leguminosites ingaefolia Berry. T.
omphalobioides Lesquereux. T.
shirleyensis Berry. T.
tuscaloosensis Berry. T.

Order Geraniales.

Family Rutaceae.

Citrophyllum aligerum (Lesquereux) Berry. T.

Family Euphorbiaceae.

Crotonophyllum panduraeformis Berry. T.
Manihotites georgiana Berry. E, R.

Order Sapindales.

Family Ilicaceae.

Ilex masoni Lesquereux. T.

Family Celastraceae.

Celastrophyllum decurrens Lesquereux. T.
shirleyensis Berry. T.
undulatum Newberry. T.
newberryanum Hollick. T.
grandifolium Newberry. T.
carolinensis Berry. T.
crenatum Heer. T.
crenatum ellipticum Berry. T.
alabamensis Berry. T.
brittonianum Hollick. T.
gymindaefolium Berry. T.
praecrassipes Berry. T.

Family Sapindaceae.

Sapindus variabilis Berry. T.
morrisoni Heer. T.

Order Rhamnales.

Family Rhamnaceae.

Zizyphus lamarensis Berry. T.
laurifolius Berry. E.
Paliurus upatoiensis Berry. E.
Eorhamnidium cretaceum Berry. T.
platyphylloides (Lesquereux) Berry. T.
Rhamnus tenax Lesquereux. T.

Family Vitaceae.

Cissites formosus Heer. T.
crispus Velenovsky. R.

Order Malvales.

Family Tiliaceae.

Grewiopsis formosa Berry. T.
tuscaloosensis Berry. T.

Family Sterculiaceae.

Pterospermites carolinensis Berry. T.
Sterculia snowii tennesseensis Berry. R.

Order Thymeleales.

Family Lauraceae.

Cinnamomum newberryi Berry. T, E.
heerii Lesquereux? E.
sp. R.
Persea valida Hollick. T.
Oreodaphne shirleyensis Berry. T.
alabamensis Berry. T.
Sassafras acutilobum Lesquereux. T.
Malapoenna cottondalensis Berry. T.
cretacea (Lesquereux) Knowlton. T.
falcifolia (Lesquereux) Knowlton. T.
horrellensis Berry. E.
Laurus plutonia Heer. T, E.
Laurophyllum nervillosum Hollick. T.
angustifolium Newberry. T.
elegans Hollick. E.

Order Myrtales.

Family Myrtaceae.

Eugenia tuscaloosensis Berry. T.
Eugenia (?) anceps Berry. R.
Eucalyptus latifolia Hollick. T.
geinitzi (Heer) Heer. T.
angusta Velenovsky. E.
Myrcia havanensis Berry. E, R.

Family Combretaceae.

Conocarpites formosus Berry. T.

Order Umbellales.

Family Araliaceae.

Aralia cottondalensis Berry. T.
eutawensis Berry. E.
Panax cretacea Heer. T.

Family Cornaceae.

Nyssa snowiana Lesquereux. T.
Cornophyllum vetustum Newberry. T.
obtusatum Berry. T.

Order Ericales (?).

Family Ericaceae.

Andromeda novaecaesareae Hollick. T, R.
grandifolia Berry. T.
parlatorii Heer. T, E.
wardiana Lesquereux. T, E.
cretacea Lasquereux ? E.
Dermatophyllites acutus Heer. T.
Kalmia brittoniana Hollick. T.

Order Primulales.

Family Myrsinaceae.

Myrsine gaudini (Lesquereux) Berry. T.
borealis Heer. T.

Order Ebenales.

Family Ebenaceae.

Diospyros primaeva Heer. T, E.
amboyensis Berry. T.
rotundifolia Lesquereux. T.

Family Sapotaceae.

Sapotacites ettingshauseni Berry. T.
shirleyensis Berry. T.
formosus Berry. T.

Order Gentianales.

Family Asclepiadaceae.

Acerates amboyensis Berry. T.

Order Polemoniales.

Family Borraginaceae.

Cordia apiculata (Hollick) Berry. T.

Position uncertain.

Tricalycites papyraceus Hollick. T.
Calycites sexpartitus Berry. T.
Carpolithus floribundus Newberry. T.
tuscaloosensis Berry. T.
Phyllites asplenoides Berry. E.
shirleyensis Berry. T.
pistiaeformis Berry. T.

TUSCALOOSA FORMATION.

HISTORICAL SKETCH.

The Tuscaloosa formation was named by Smith and Johnson[1] in 1887 after the city and the river (now usually known as the Warrior or Black Warrior River) of that name in Alabama. Earlier observers had noticed the presence of sands and clays below the recognized Cretaceous and above the Carboniferous. Lewis Harper,[2] the State geologist of Mississippi, mentioned them in print as early as 1856 and suggested that their age was perhaps Permian or even Triassic. The same year Alexander Winchell mentioned the mottled clays of Tuscaloosa, calling attention to the contained vegetable remains "appearing like the stems and leaves of dicotyledonous plants." He doubted their Triassic age and in his table of formations failed to assign a definite age to them. Meek and Hayden[3] in discussing the Alabama Mesozoic mentioned the presence of wood and leaves and correlated the lower part with the lowest Cretaceous of New Jersey and Nebraska. Their lithologic characterization clearly indicates that they are discussing the Tuscaloosa, and they say that although the weight of evidence favors the correlating of these beds with the Neocomian of the Old World, positive evidence is lacking that a part may not be older than Cretaceous. Subsequently E. W. Hilgard[4] described the beds in Mississippi beneath his Tombigbee sands as the Eutaw group and referred them to the Cretaceous. The following year Meek and Hayden restated their views and definitely correlated the beds in Alabama with the Dakota sandstone of the Western Interior.[5] Again in 1876 Meek[6] reaffirms his belief that the basal Cretaceous of Alabama is of the same age as the plastic clays of New Jersey and the Dakota sandstone of the Upper Missouri section.

All these geologists failed to discriminate the Tuscaloosa from the overlying, mostly unfossiliferous sands and laminated clays of what is now known as the Eutaw formation. The first reasonably complete account of the Tuscaloosa formation is that given by Smith and Johnson in the publication above referred to. From the attitude, lithologic character, and stratigraphic position of the beds they correlated the Tuscaloosa with the Potomac of the middle Atlantic slope which had just been named and briefly described by McGee.[7] This correlation was natural, because the Potomac as understood in the earlier days included beds which according to the opinions of different students were referred to various levels ranging from the Triassic to the Cretaceous and which subsequent study has shown constitute a series of well-marked formations, the oldest of Neocomian age and the youngest of Cenomanian age.

From 1883 to the present time Dr. E. A. Smith, the State geologist of Alabama, has added to our knowledge of these deposits, being assisted in the beginning by L. C. Johnson and D. W. Langdon, jr. The discovery of all the noteworthy localities for fossil plants is due to their efforts. In 1884 some leaf impressions collected by Langdon in Bibb County were submitted to Leo Lesquereux, and among them he recognized a species of *Podozamites*, which he thought might indicate a pre-Cretaceous age. Lesquereux afterward determined a small collection of leaves from the Tuscaloosa formation at Tuscaloosa, but this list seems never to have been published.[1]

---

[1] Smith, E. A., and Johnson, L. C., Tertiary and Cretaceous strata of the Tuscaloosa, Tombigbee, and Alabama rivers: U. S. Geol. Survey Bull. 43, p. 95, 1887.

[2] Acad. Nat. Sci. Philadelphia Proc., vol. 8, pp. 126–128, 1856.

[3] Idem, vol. 9, pp. 117–133, 1857.

[4] Report on the geology and agriculture of the State of Mississippi, p. 61, 1860.

[5] Acad. Nat. Sci. Philadelphia Proc., vol. 13, pp. 419–421, 1861.

[6] Meek, F. B., A report on the invertebrate Cretaceous and Tertiary fossils of the Upper Missouri country: U. S. Geol. and Geog. Survey Terr. Rept., vol. 9, pp. 38–42, 1876.

[7] McGee, W J, [Geology of Washington and vicinity]: Report of the health officer of the District of Columbia for the year ending June 30, 1885, pp. 19–21, 23–35, 1886.

In 1886 Smith and Langdon discovered several localities for fossil plants in the vicinity of Tuscaloosa (Cottondale, Snow plantation, and Tuscaloosa) and the next year the United States Geological Survey sent W. M. Fontaine into the field. He made large collections of mostly fragmentary material from those outcrops as well as from one or two other outcrops near Tuscaloosa. In 1892 L. F. Ward visited Alabama and with Dr. Smith made extensive collections from Glen Allen and Shirleys Mill. These collections received a preliminary study by Ward, who furnished a list of 35 species which was published by Smith in 1894 in his report on the geology of the Coastal Plain of Alabama. This list enumerated the following forms:

Andromeda latifolia Newberry=Andromeda grandifolia Berry.
Andromeda novaecalcareae Hollick (novaecaesareae).
Andromeda parlatorii Heer.
Aralia wellingtoniana Lesquereux=Aralia cottondalensis Berry.
Carpolithus floribundus Newberry.
Celastrophyllum crenatum Heer.
  undulatum Newberry.
Cinnamomum intermedium Newberry=Cinnamomum newberryi Berry.
Cladophlebis parva Fontaine=Cladophlebis alabamensis Berry.
Cycadinocarpus circularis Newberry.
Czekanowskia capillaris Newberry.[2]
Dewalquea groenlandica Heer.
Diospyros primaeva Heer.
Eucalyptus attenuata Newberry.[2]
  nervosa Newberry.[2]
  parvifolia Newberry.[2]
Ficus inaequalis Lesquereux.
  lanceolato-acuminata Newberry.[2]
  woolsoni Newberry.
Liriodendropsis angustifolia Newberry.
  simplex Newberry.
Magnolia alternans Heer.[2]
  auriculata Newberry.
  glaucoides Newberry=Magnolia boulayana Lesquereux.
  longifolia Newberry.
  speciosa Heer.
Myrsine borealis Heer.
Populus apiculata Newberry=Cordia apiculata Berry.
Proteoides daphnogenoides Heer=Ficus daphnogenoides Berry.
Pterospermites modestus Lesquereux.[2]
Sequoia gracillima Lesquereux, Newberry=Widdringtonites reichii (Ettingshausen) Heer.
  heterophylla Velenovsky.
  reichenbachii (Geinitz) Heer.
Tricalycites papyraceus Newberry.
Widdringtonites reichii (Ettingshausen) Heer.

I spent the field season of 1909 revisiting all of the known plant localities in Alabama and making extensive collections in preparation for this report. Accompanied by L. W. Stephenson I studied the Black Warrior and Tombigbee river sections during a trip down those rivers in a launch from Tuscaloosa, Ala., to the Eocene contact at Moscow, Ala.; I traversed Coosa and Alabama rivers from Wetumpka to Montgomery, Ala., Chattahoochee River from Columbus to Gainesville, Ga., and upper Tombigbee River in Mississippi, and visited localities in Tishomingo, Prentiss, and Itawamba counties, Miss. I have also used the collections and notes made by Mr. Stephenson in his extensive field and office studies on the stratigraphy and paleontology of the Cretaceous of the eastern Gulf area.

AREAL DISTRIBUTION.

The Tuscaloosa formation outcrops as a belt of varying width along the southwestern border of all four of the physiographic divisions of the southern Appalachian province. These divisions are, in order from northwest to southeast, the Interior Lowlands, the Cumberland Plateau, the Appalachian Valley, and the Piedmont Plateau. This area of outcrop, which amounts to about 6,500 square miles, is almost exactly lunate in outline, one horn terminating at the Tennessee boundary in northeastern Mississippi and the other near Montgomery in east-central Alabama. Its length is about 250 miles, and the chord of the arc is almost exactly at right angles with the axis of the Appalachian Mountains.[3]

LITHOLOGIC CHARACTER.

The materials are predominantly sandy and give rise to the broken, uneven topography of the present day. These sands are usually light in color, cross-bedded, and micaceous and contain in places, particularly landward and northward, considerable gravel and pebble beds, made up of both well-rounded quartz and angular chert in about equal proportions. In disconnected and interbedded lenses there is a large amount of argillaceous material which is in places massive and in places laminated. Seams of lignite of inconsiderable thickness are present at various levels, for example, 2 miles east of Tuscaloosa near the base of the Tuscaloosa formation a seam occurs several inches thick; and toward the top of the Tuscaloosa, in Itawamba County, Miss., lies a persistent bed of lignite, nearly 2 feet thick, which in the earlier days of the county led to the formation of a coal company. Very lignitic clays are seen in many sections, a layer in the section at Big Gully, southwest of Tuscaloosa, being filled with prostrate logs of large size. Pyrite and ferruginous oxide forming locally indurated sandstones are generally distributed. The lignite beds or lignitic clays commonly contain globules of amber, and finely disseminated gypsum crystals are seen at various levels.

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[1] Smith, E. A., Geological map and explanatory chart of Alabama, Alabama Geol. Survey, 1894.

[2] Not recognized by me.

[3] Undifferentiated Tuscaloosa or Eutaw deposits are shown on the map to extend across Tennessee and into western Kentucky.

The clays of the lower part of the Tuscaloosa are more extensive, more massive, and thicker than in the corresponding Upper Cretaceous from Cape Cod to Texas except in the Raritan formation of Middlesex County, N. J. Like the Raritan they represent nonmarine sediments although marine waters were near by. This fact is attested by temporary incursions of marine faunas in the Raritan and by the presence of glauconite and gypsum in the Tuscaloosa. Some of this gypsum seems unquestionably to be secondary in origin as in the large radiating crystals so abundant in the gully on the Snow plantation, but the finely disseminated needles of gypsum, as in the Sanders Ferry Bluff section, are usually regarded as of primary and not of secondary origin. Continental deposits have probably helped to make up the thickness of the Tuscaloosa. The great bulk of the Tuscaloosa flora comes from western Alabama in the area from Cottondale northwest to Glen Allen. East of Cottondale identifiable plant remains are sporadic in their occurrence, but northwest of Glen Allen they are practically absent and the few plants found in northeastern Mississippi prove that the base of the Tuscaloosa is progressively younger toward the head of the embayment. A reasonable explanation is furnished by the delta type of sediments and the probable Cretaceous drainage lines southwestward in the structural lines of the folded Carboniferous rocks. This view of the Cretaceous physiography is by no means new, having been elaborated by Hayes[1] in 1899.

The basal purplish clays around Tuscaloosa seem to be replaced by basal sands in northern Fayette County. These sands are coarse, with large and small pebbles, in places with well-rounded quartz cobbles and angular cobbles of Carboniferous sandstone. About half the pebbles are rounded quartz, and the remainder are angular chert. In places the sands are filled with fragments of chert the size of buckshot. The Carboniferous surface is undulating and in places approaches close to the surface. It is exposed in the stream channels and rises to form the cores of many of the hills between Fayette and Glen Allen. These hills were probably in existence during Tuscaloosa time. The local lithologic variations will not be described in the present connection as they have been discussed at length by Smith and more recently by Stephenson, and they are sufficiently illustrated in the sections carrying plant remains which are subsequently discussed (pp. 15–22).

The strike of the beds is parallel with the shore line of the old land mass which they skirt, and their dip conforms to the gently warped surface of the Cumberland peneplain. Their total thickness in western Alabama is estimated by Smith to be about 1,000 feet, but they become thin in a short distance north.

In northeastern Mississippi their maximum thickness, as determined by the city waterworks well at Corinth, is about 270 feet, and although they probably were transgressed by the overlying Eutaw in this northern area, they have not been recognized north of the Tennessee-Mississippi boundary in either surface outcrops or well borings, except as sands or gravels which have been mapped as undifferentiated Tuscaloosa and Eutaw and which are interpreted as a series of coarse sediments resulting from physiographic changes covering an interval extending from Tuscaloosa into Eutaw time. These changes are discussed on pages 26–29.

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[1] Hayes, C. W., Physiography of the Chattanooga district, in Tennessee, Georgia, and Alabama: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, pp. 1–58, 1899.

STRATIGRAPHIC RELATIONS.

In the easternmost part of their outcrop the Tuscaloosa deposits may rest upon the Lower Cretaceous sediments that enter eastern Alabama from Georgia and disappear in the longitude of Montgomery, particularly as these Lower Cretaceous sediments are supposed to have once been continuous with those of the western Gulf region. However, the unlithified and unfossiliferous character of all the deposits at this point has thus far prevented a determination of their precise limitation and relations.

From the western part of Elmore County northwestward to the central part of Chilton County, a distance of about 40 miles, the Tuscaloosa rests upon the crystalline igneous and metamorphic rocks of the Piedmont Plateau. From Chilton County northwestward to their disappearance as continuous beds in northeastern Mississippi, the Tuscaloosa sediments rest on the limestones, shales, and sandstones of the Mississippian and Pennsylvanian series of the Carboniferous. They are overlain throughout their extent by the somewhat similar shallow-water sediments forming the basal part of the Eutaw formation.

LOCAL SECTIONS CONTAINING PLANT REMAINS.

The detailed areal distribution and lithology of the Tuscaloosa formation will probably be fully discussed in a subsequent Survey publication by L. W. Stephenson in connection with his Cretaceous faunal studies, so that any extended discussion is not necessary in this report. Therefore only a few of the more important outcrops where fossil plants have been collected will be described in the following pages.

NEAR IUKA, MISS.

The most northerly plant-bearing outcrop of the Tuscaloosa formation is that in the cut of the Southern Railway 1⅝ miles east of Iuka, in Tishomingo County, Miss. (See Pl. III, *B*.) The exposure is not extensive but shows, according to Stephenson, a basal conglomerate overlain by lignitic, argillaceous, very micaceous sands. An interesting feature of this and other outcrops in northeastern Mississippi is the abundance of amber, which occurs in pieces ranging from tiny globules to pellets about the size of marbles, that found near Iuka showing distinct evidence of having been rolled and waterworn. The fossil plants found at this locality are few in number and poorly preserved. They include the four forms *Andromeda wardiana*, *Androvettia carolinensis*, *Phyllites pistiaeformis*, and *Sequoia reichenbachi*, of which the last is typical and very abundant. These forms are all significant in their bearing on the relative age of the deposit, and though the *Andromeda* and *Phyllites* occur in the Alabama Tuscaloosa, both are rare, and usually the rare plants are not found at localities where the representation of the flora is small. The *Androvettia* is common to the Black Creek formation of North Carolina, and though the *Sequoia* occurs in the Alabama Tuscaloosa as well as in the New Jersey Raritan, it is rare in both, becoming exceedingly abundant in the Magothy, Black Creek, and Eutaw formations. It seems evident that the northward extension of the Tuscaloosa in Mississippi is younger than the main body of the deposits in Alabama and represents the upper 200 or 300 feet of the Tuscaloosa as developed in west-central Alabama.

Plant remains are recorded by Smith, on the authority of L. C. Johnson, from Itawamba County, Miss., and this is the only locality in northeastern Mississippi where they have been found, as an extended search in the lignitic clays of that county failed to reveal any identifiable plants.

GLEN ALLEN, ALA.

The most northern plant locality known in the Alabama area is in a cut along the St. Louis-San Francisco Railway about a quarter of a mile east of Glen Allen, near the northern boundary of Fayette County. (See Pl. II, *A*.) This locality was discovered by the Geological Survey of Alabama about 25 years ago, and extensive collections were made here by E. A. Smith and L. F. Ward in 1892. These were supplemented by collections made by Berry and Stephenson in 1909. This locality is the one erroneously stated by Smith to be in Marion County.[1] The outcrop extends about 150 yards on both sides of the track and is shown diagrammatically in figure 1. An examination of material obtained from dug wells

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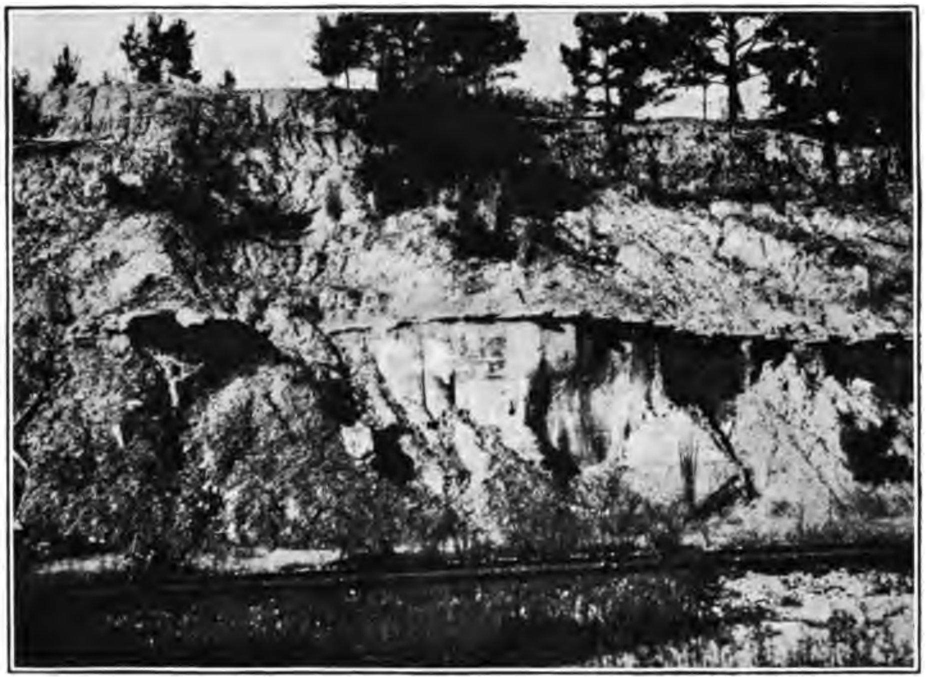
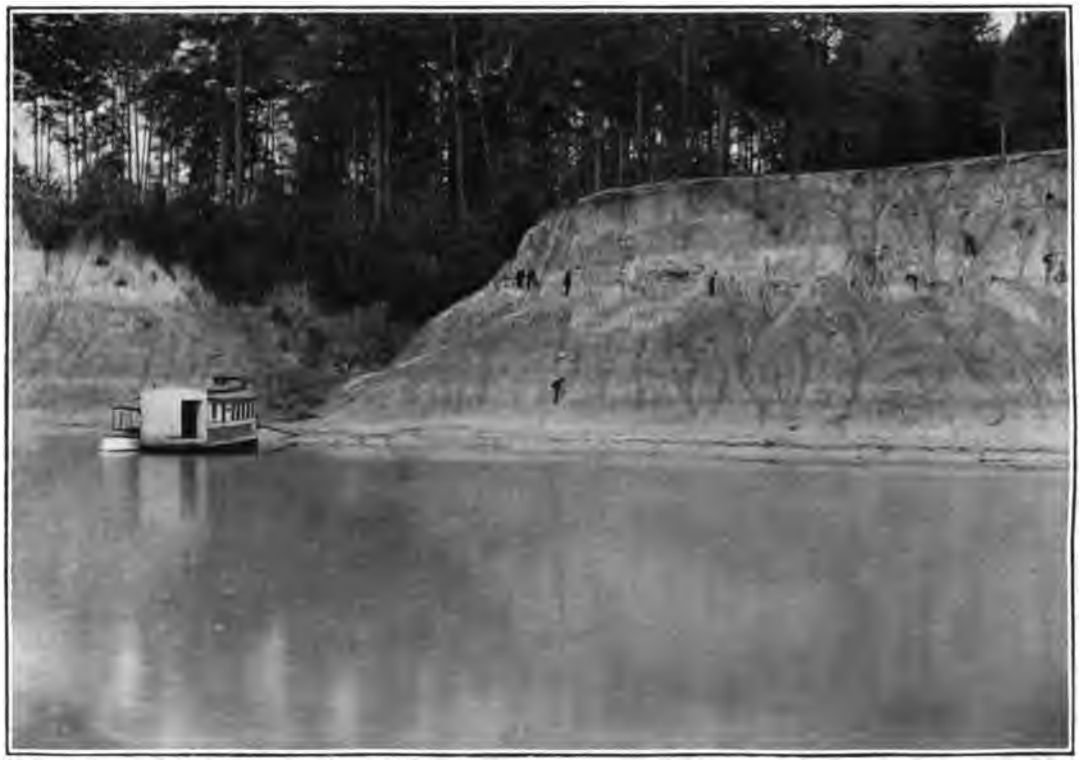
[1] Smith, E. A., Langdon, D. W., jr., and Johnson, L. C., On the geology of the Coastal Plain of Alabama, Cretaceous, Tertiary, and post-Tertiary formations, p. 331, Alabama Geol. Survey, 1894.



A. CUT IN THE TUSCALOOSA FORMATION NEAR GLEN ALLEN, ALA., ALONG THE ST. LOUIS-SAN FRANCISCO RAILWAY, SHOWING SANDS BELOW THE FERRUGINOUS LEDGE AND LEAF-BEARING CLAYS ABOVE.



B. WHITES BLUFF, BLACK WARRIOR RIVER, ALA., SHOWING SANDS AND LEAF-BEARING CLAYS OF THE TUSCALOOSA FORMATION.

and near-by exposures shows the leaf-bearing stratum to be about 90 feet above the Paleozoic floor. The beds represented by this thickness are predominantly sandy and extensively current-bedded. Above a ferruginous ledge there is a dark, tough plastic clay, rather massively bedded at the base and becoming laminated above. This is the leaf-bearing horizon, and the best materials were collected from the lower half of the member. The following 39 species have been recognized:

Andromeda grandifolia Berry.
    novaecaesareae Hollick.
    parlatorii Heer.
Bauhinia marylandica Berry.
Cassia vaughani Berry.
Cinnamomum newberryi Berry.
Cissites formosus Heer.
Cocculus problematicus Berry.
Conocarpites formosus Berry.
Cordia apiculata (Hollick) Berry.
Cornophyllum vetustum Newberry.
Cycadinocarpus circularis Newberry.
Diospyros primaeva Heer.
    rotundifolia Lesquereux.
Ficus daphnogenoides (Heer) Berry.
    krausiana Heer.
    woolsoni Newberry.
Ilex masoni Lesquereux.
Leguminosites ingaefolia Berry.
Liriodendropsis simplex Newberry.
Lycopodites tuscalooensis Berry.
Lycopodium cretaceum Berry.
Magnolia lacoeana Lesquereux.
    newberryi Berry.
    speciosa Heer.
Marattia cretacea Velenovsky?
Myrica dakotensis minima Berry.
Myrsine borealis Heer.
    gaudini (Lesquereux) Berry.
Persoonia lesquereuxii minor Berry.
Phyllites pistiaeformis Berry.
Populites tuscaloosensis Berry.
Pterospermites carolinensis Berry.
Salix lesquereuxii Berry.
Sapindus variabilis Berry.
Sphaerites alabamensis Berry.
Tricalycites papyraceus Newberry.
Widdringtonites reichii (Ettingshausen) Heer.
Zizyphus lamarensis Berry.

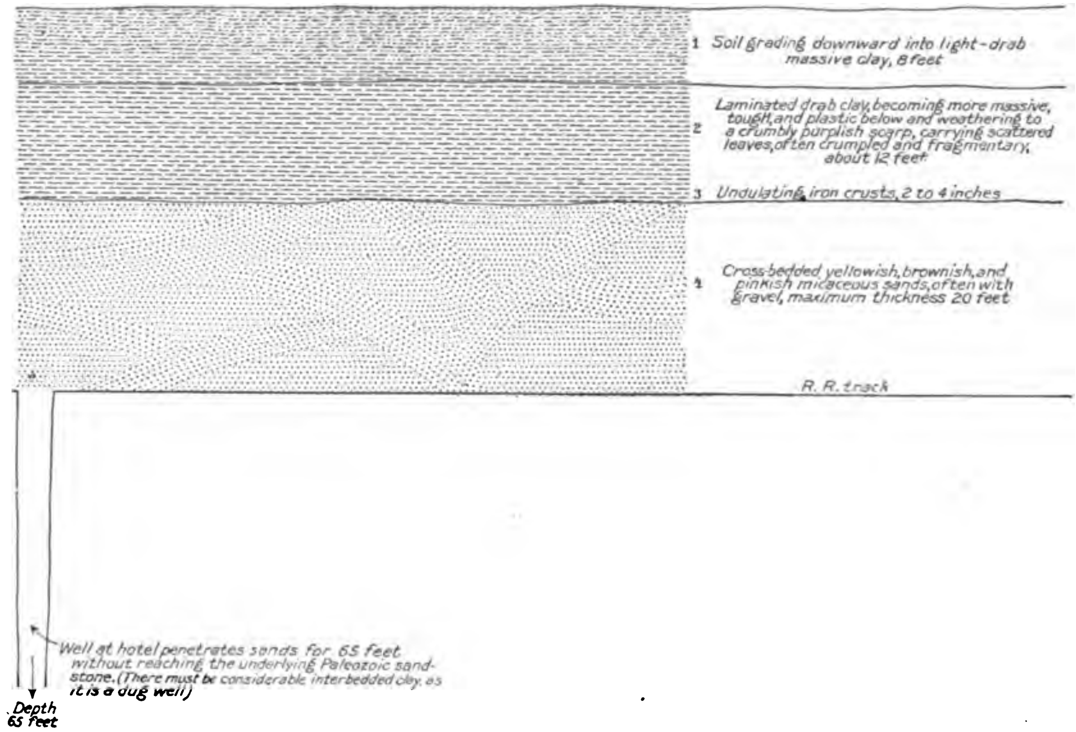

1 Soil grading downward into light-drab massive clay, 8 feet
2 Laminated drab clay, becoming more massive, tough, and plastic below and weathering to a crumbly purplish scarp, carrying scattered leaves, often crumpled and fragmentary, about 12 feet
3 Undulating iron crusts, 2 to 4 inches
4 Cross-bedded yellowish, brownish, and pinkish micaceous sands, often with gravel, maximum thickness 20 feet
R. R. track
Well at hotel penetrates sands for 65 feet without reaching the underlying Paleozoic sandstone. (There must be considerable interbedded clay, as it is a dug well)
Depth 65 feet

FIGURE 1.—Section of the Tuscaloosa formation in an exposure at Glen Allen, Fayette County, Ala.

This outcrop is between 20 and 25 miles directly north of the Shirleys Mill locality and is about the same distance above the base of the formation as the exposure at Shirleys Mill. Notwithstanding its proximity and similar stratigraphic position, 14 of the 39 species do not occur in the larger collections from the latter locality. The significant lithologic features of this and near-by sections are the coarseness of the sands and their current bedding, the abundance of gravels, pebbles, and cobbles, the quartz cobbles being well rounded and those of Carboniferous sandstone rather angular. The sands, gravels, and pebbles are estimated to be about half angular chert and half well-rounded quartz, showing that Carboniferous elements in the Tuscaloosa were not transported very far.

SHIRLEYS MILL, ALA.

About 25 miles south of Glen Allen, in the southern part of Fayette County, Davis Creek, a small branch of Sipsey River, has cut its valley nearly through the Tuscaloosa mantle. The plant-bearing clays outcrop along the old Fayette-Tuscaloosa coach road about 10 miles southeast of Fayette courthouse, where the road dips sharply to Davis Creek bottom. (See Pl. III, *A*.) This locality was discovered by the Geological Survey of Alabama and collections were made from it in 1892 by Smith and Ward. A larger amount of better-preserved material was obtained by Berry and Stephenson in 1909. The section is shown graphically in figure 2.

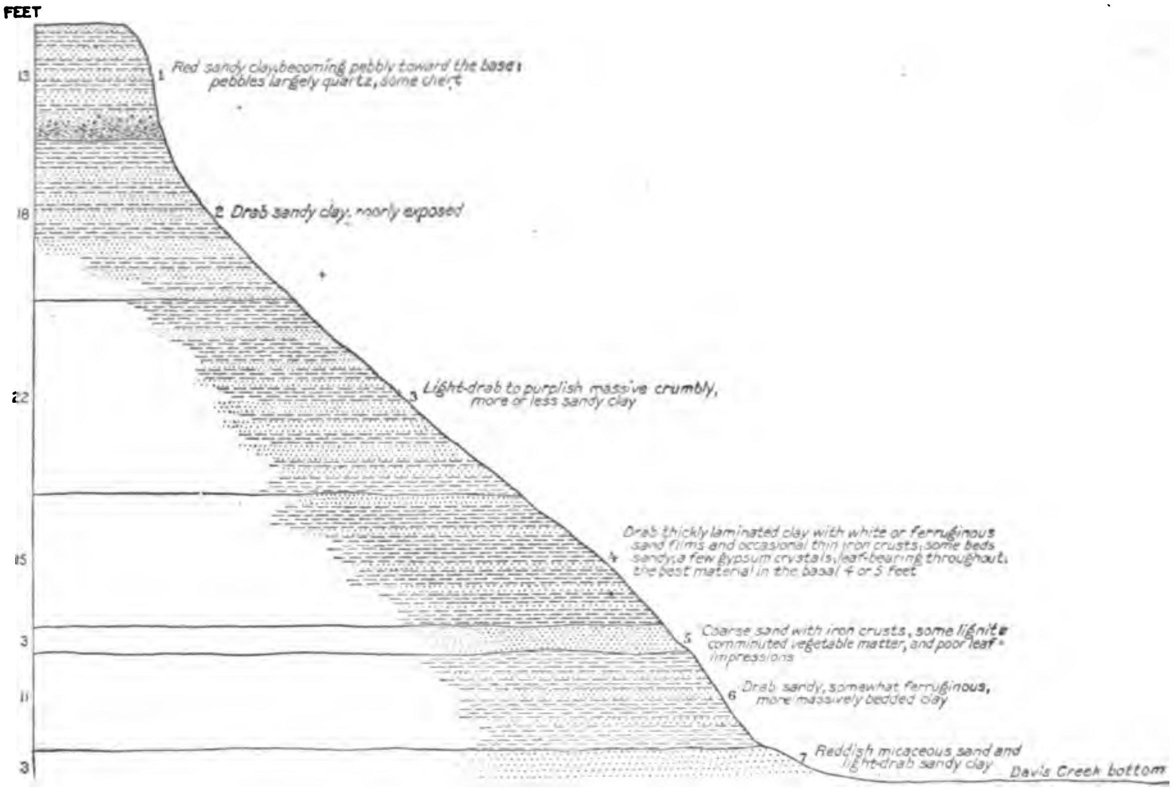
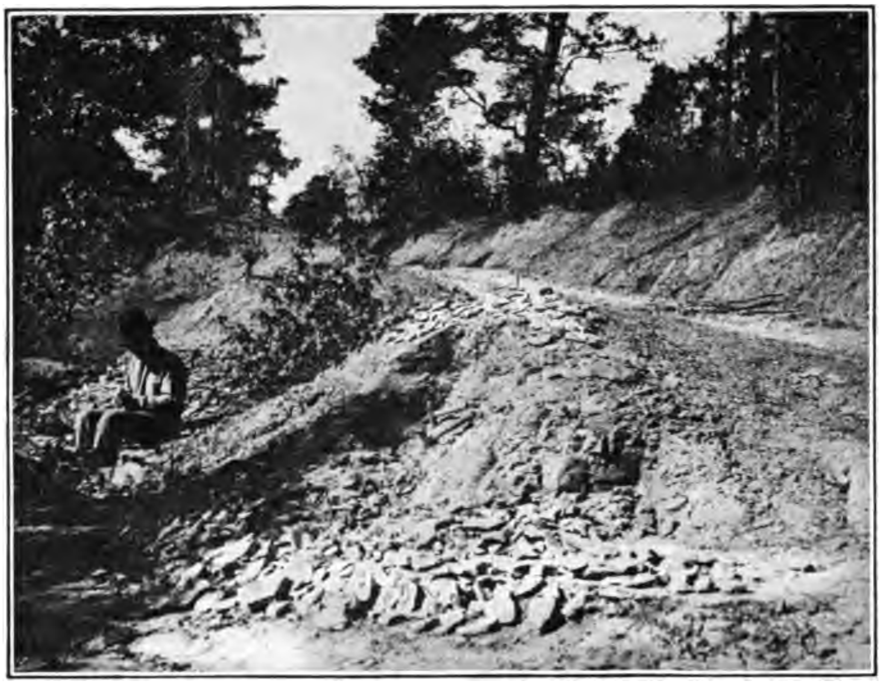
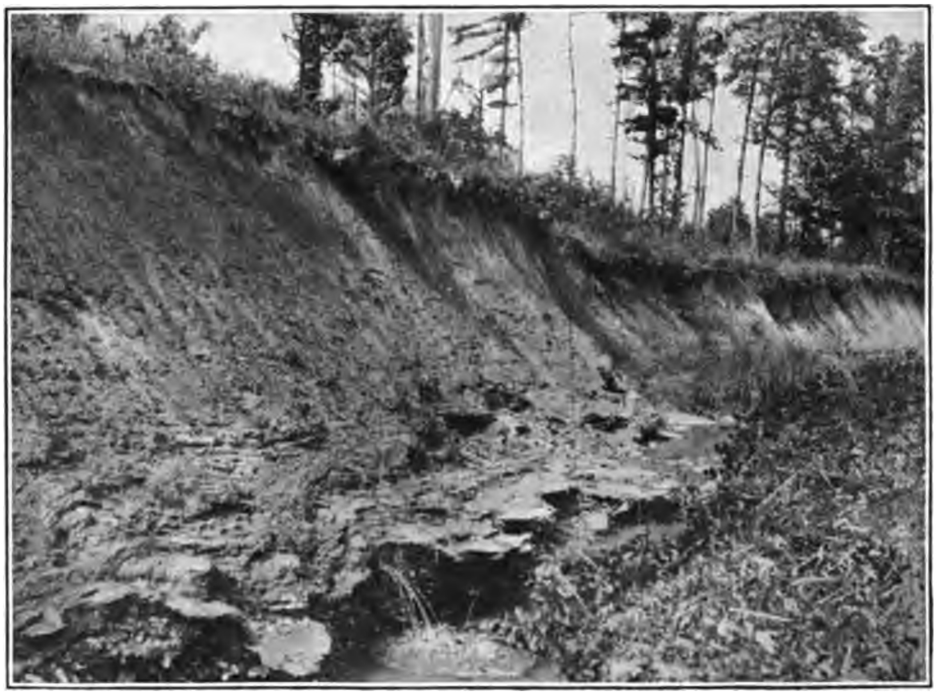

FEET
13
18
22
15
3
11
3
1 Red sandy clay, becoming pebbly toward the base; pebbles largely quartz, some chert
2 Drab sandy clay, poorly exposed
3 Light-drab to purplish massive crumbly, more or less sandy clay
4 Drab thickly laminated clay with white or ferruginous sand films and occasional thin iron crusts; some beds sandy; a few gypsum crystals; leaf-bearing throughout; the best material in the basal 4 or 5 feet
5 Coarse sand with iron crusts, some lignite comminuted vegetable matter, and poor leaf impressions
6 Drab sandy, somewhat ferruginous, more massively bedded clay
7 Reddish micaceous sand and light-drab sandy clay
Davis Creek bottom

FIGURE 2.—Section of the Tuscaloosa formation (beds Nos. 2 to 7, inclusive), in an exposure near Shirleys Mill, 10 miles southeast of Fayette, Fayette County, Ala.

Argillaceous materials predominate throughout nearly the entire section, although the clays are often sandy. About 20 feet above the base of the section and not far above the underlying Paleozoic floor there is a stratum of about 15 feet of brownish, thickly laminated, rather pure clay with thin films of fine white sand, which carries an abundance of leaves, the best material coming from the basal 4 or 5 feet. The leaves are the best preserved of any that I have found in the Tuscaloosa. They are not in matted layers but evenly distributed, most of them lying flat, with petioles attached and the dripping points of the long slender leaves unbroken. The prevailing fineness of the sediments and the lack of any evidence of trituration of the fossils show that the waters were quiet and that the plants grew near shore. The regular vertical distribution and lack of closely packed layers indicate no less clearly that the leaves were not deciduous, but that they dropped one by one throughout the year into what was a quiet delta lake or sluggish bayou, whose shores were mantled with a varied arborescent flora. In a collecting experience in the Coastal Plain Cretaceous extending from Long Island to Texas I know of no localities as satisfactory as this one. Some of the clays of the Middendorf arkose member of the Black Creek formation in South Caro-



A. ROADSIDE WASH IN THE TUSCALOOSA FORMATION NEAR SHIRLEYS MILL, ALA., EXPOSING HIGHLY FOSSILIFEROUS CLAYS.



B. VIEW SHOWING BASAL GRAVEL OVERLAIN BY LAMINATED CLAYS OF THE TUSCALOOSA FORMATION, BEARING LEAVES, LIGNITE, AND AMBER, 1½ MILES EAST OF IUKA.

lina carry equally good material, but it is neither so abundant nor so varied. I have identified the following 98 different species from this outcrop:

- Acerates amboyensis Berry.
- Andromeda grandifolia Berry.
  - novaecaesareae Hollick.
  - parlatorii Heer.
  - wardiana Lesquereux.
- Asplenium dicksonianum Heer.
- Bauhinia cretacea Newberry.
  - marylandica Berry.
- Brachyphyllum macrocarpum formosum Berry.
- Capparites cynophylloides Berry.
  - orbiculatus Berry.
- Carpolithus floribundus Newberry.
- Celastrophyllum brittonianum Hollick.
  - crenatum ellipticum Berry.
  - decurrens Lesquereux.
  - grandifolium Newberry.
  - gymindaefolium Berry.
  - newberryanum Hollick.
  - praecrassipes Berry.
  - shirleyensis Berry.
- Cinnamomum newberryi Berry.
- Citrophyllum aligerum (Lesquereux) Berry.
- Colutea obovata Berry.
- Cordia apiculata (Hollick) Berry.
- Crotonophyllum panduraeformis Berry.
- Dammara borealis Heer.
- Dermatophyllites acutus Heer.
- Dewalquea smithi Berry.
- Dicksonia groenlandica Heer.
- Diospyros amboyensis Berry.
  - primaeva Heer.
  - rotundifolia Lesquereux.
- Eorhamnidium cretaceum Berry.
- Eugenia tuscaloosensis Berry.
- Ficus alabamensis Berry.
  - daphnogenoides (Heer) Berry.
  - fontainii Berry.
  - inaequalis Lesquereux.
  - krausiana Heer.
  - shirleyensis Berry.
  - woolsoni Newberry.
- Geinitzia formosa Heer.
- Gleichenia delicatula Heer.
- Grewiopsis formosa Berry.
  - tuscaloosensis Berry.
- Hymenaea fayettensis Berry.
- Inga cretacea Lesquereux.
- Juglans arctica Heer.
- Jungermannites cretaceus Berry.
- Kalmia brittoniana Hollick.
- Laurophyllum nervillosum Hollick.
- Laurus plutonia Heer.
- Leguminosites ingaefolia Berry.
  - omphaloboides Lesquereux.
  - shirleyensis Berry.
  - tuscaloosensis Berry.
- Liriodendropsis angustifolia Newberry.
  - constricta Ward.
  - simplex Newberry.
- Lycopodites tuscaloosensis Berry.
- Lycopodium cretaceum Berry.
- Magnolia boulayana Lesquereux.
  - hollicki Berry.
  - lacoeana Lesquereux.
  - longipes Newberry.
  - obtusata Heer.
  - speciosa Heer.
- Malapoenna falcifolia (Lesquereux) Knowlton
- Menispermites trilobatis Berry.
- Myrica emarginata Heer.
- Myrsine borealis Heer.
- Nyssa snowiana Lesquereux.
- Oreodaphne shirleyensis Berry.
- Palaeocassia laurinea Lesquereux.
- Panax cretacea Heer.
- Persoonia lesquereuxii Knowlton.
  - lesquereuxii minor Berry.
- Phaseolites formus Lesquereux.
- Phyllites shirleyensis Berry.
- Piperites tuscaloosensis Berry.
- Platanus asperaeformis Berry.
  - shirleyensis Berry.
- Proteoides conospermafolia Berry.
- Protodammara speciosa Hollick and Jeffrey.
- Pterospermites carolinensis Berry.
- Rhamnus tenax Lesquereux.
- Salix flexuosa Newberry.
  - lesquereuxii Berry.
  - meekii Newberry.
- Sapindus variabilis Berry.
- Sapotacites ettingshauseni Berry.
  - formosus Berry.
  - shirleyensis Berry.
- Sequoia heterophylla Velenovsky.
- Sphaerites alabamensis Berry.
- Tricalycites papyraceus Newberry.
- Widdringtonites reichii (Ettingshausen) Heer.
  - subtilis Heer.

TUSCALOOSA, ALA.

Following a strictly geographic order there are several localities in and immediately around the town of Tuscaloosa to be briefly considered. The sections exposed are not extensive nor of especial significance and will not be discussed. The plants also are few and as a rule not especially well preserved. Two of these localities are on the university grounds and one on the site of the hydraulic laboratory, from which specimens were collected many years ago that bear the labels "Bathhouse, university grounds." A few plants have also been collected by E. A. Smith in a railroad cut just east of Tuscaloosa and from the banks of

Black Warrior River in the town. A light-colored, thinly laminated clay with rather well preserved leaves of little variety outcrops in a ravine leading down to Black Warrior River. Fontaine made a collection from this outcrop in 1887 and the locality is stated as "Back of Menges livery stables near Lynch House," referring to two establishments that have since disappeared. An additional locality is a roadside outcrop a few miles southwest of Tuscaloosa from which Fontaine collected specimens in 1887. This locality is referred to in the systematic chapter as "southwest of Northport." The plants from all of these localities are grouped under "Tuscaloosa" in the table of distribution.

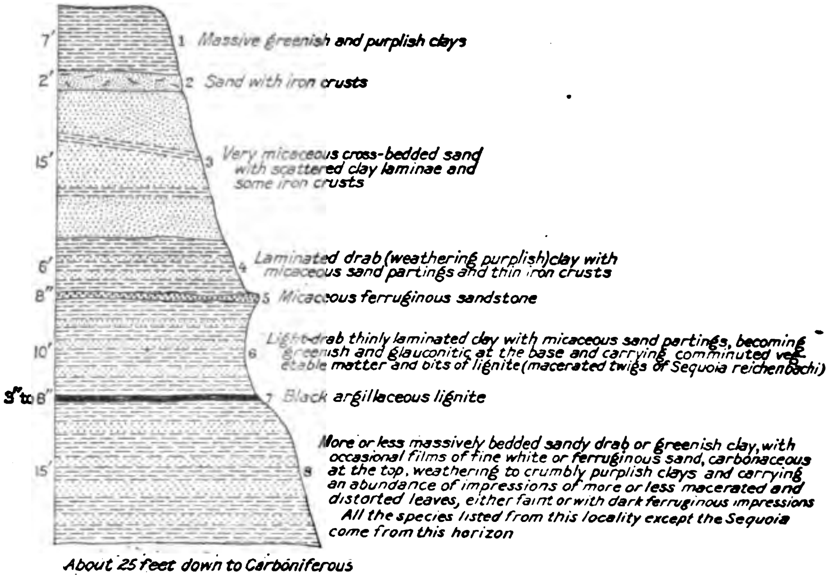

7'
1 Massive greenish and purplish clays
2'
2 Sand with iron crusts
15'
3 Very micaceous cross-bedded sand with scattered clay laminae and some iron crusts
6'
4 Laminated drab (weathering purplish) clay with micaceous sand partings and thin iron crusts
8"
5 Micaceous ferruginous sandstone
10'
6 Light-drab thinly laminated clay with micaceous sand partings, becoming greenish and glauconitic at the base and carrying comminuted vegetable matter and bits of lignite (macerated twigs of Sequoia reichenbachi)
3" to 8"
7 Black argillaceous lignite
15'
8 More or less massively bedded sandy drab or greenish clay, with occasional films of fine white or ferruginous sand, carbonaceous at the top, weathering to crumbly purplish clays and carrying an abundance of impressions of more or less macerated and distorted leaves, either faint or with dark ferruginous impressions
All the species listed from this locality except the Sequoia come from this horizon
About 25 feet down to Carboniferous

FIGURE 3.—Section of the Tuscaloosa formation in an exposure near Cottondale, Tuscaloosa County, Ala.

COTTONDALE, ALA.

A richly fossiliferous stratum outcrops along the public road about 10 miles east of Tuscaloosa and 2 miles southeast of Cottondale. This locality is referred to as Cottondale in the general discussions and in the systematic chapter. The materials, which are argillaceous below and arenaceous above, are near the base of the formation. Carboniferous (Pottsville) sandstones outcrop in the bed of a small branch of Hurricane Creek, a short distance west of the exposure. The leaf-bearing stratum is estimated to be about 25 feet above this Paleozoic floor. The section is shown diagrammatically in figure 3. The lithology is of considerable interest, as about 15 or 20 feet above the base of the section and 50 feet or more above the base of the formation there is an extensive seam of lignite several inches thick, above which is thinly laminated clay with more or less glauconite, carrying traces of *Sequoia reichenbachi*, a species which, though not positively diagnostic of any one horizon, is entirely absent in the basal plant-bearing beds at the localities which have furnished the bulk of the Tuscaloosa flora, a species which is moreover especially prominent in the flora of the Eutaw formation. The lignite seam is too thin and argillaceous to mark a swamp surface, and sedimentation is believed not to have been interrupted. The total number of identified species from the clays at the base of this section is 47, the following forms being present:

Andromeda parlatorii Heer.
Aralia cottondalensis Berry.
Bauhinia cretacea Newberry.
  marylandica Berry.
Celastrophyllum crenatum Heer.
  grandifolium Newberry.
  undulatum Newberry.
Cinnamomum newberryi Berry.
Citrophyllum aligerum (Lesquereux) Berry.
Cocculus cinnamomeus Velenovsky?
  polycarpaefolius Berry.
Cordia apiculata (Hollick) Berry.
Cornophyllum obtusatum Berry.
Diospyros primaeva Heer.
Eorhamnidium cretaceum Berry.
  platyphylloides (Lesquereux) Berry.
Eugenia tuscaloosensis Berry.

Ficus daphnogenoides (Heer) Berry.
    fontainii Berry.
    inaequalis Lesquereux.
    krausiana Heer.
    woolsoni Newberry.
Geinitzia formosa Heer.
Ilex masoni Lesquereux.
Juglans arctica Heer.
Laurus plutonia Heer.
Liriodendron meekii Heer.
Magnolia capellinii Heer.
    longipes Newberry.
    speciosa Heer.
Malapoenna cottondalensis Berry.
    cretacea (Lesquereux) Knowlton.
Menispermites integrifolia Berry.
Myrica emarginata Heer.
Mysine gaudini (Lesquereux) Berry.
Oreodaphne alabamensis Berry.
Persea valida Hollick.
Phaseolites formus Lesquereux.
Pinus raritanensis Berry.
Platanus latior (Lesquereux) Knowlton.
    shirleyensis Berry.
Populus hyperborea Heer.
Protophyllocladus subintegrifolius (Lesquereux) Berry.
Pterospermites carolinensis Berry.
Salix lesquereuxii Berry.
Sassafras acutilobum Lesquereux.
Sequoia reichenbachii (Geinitz) Heer?

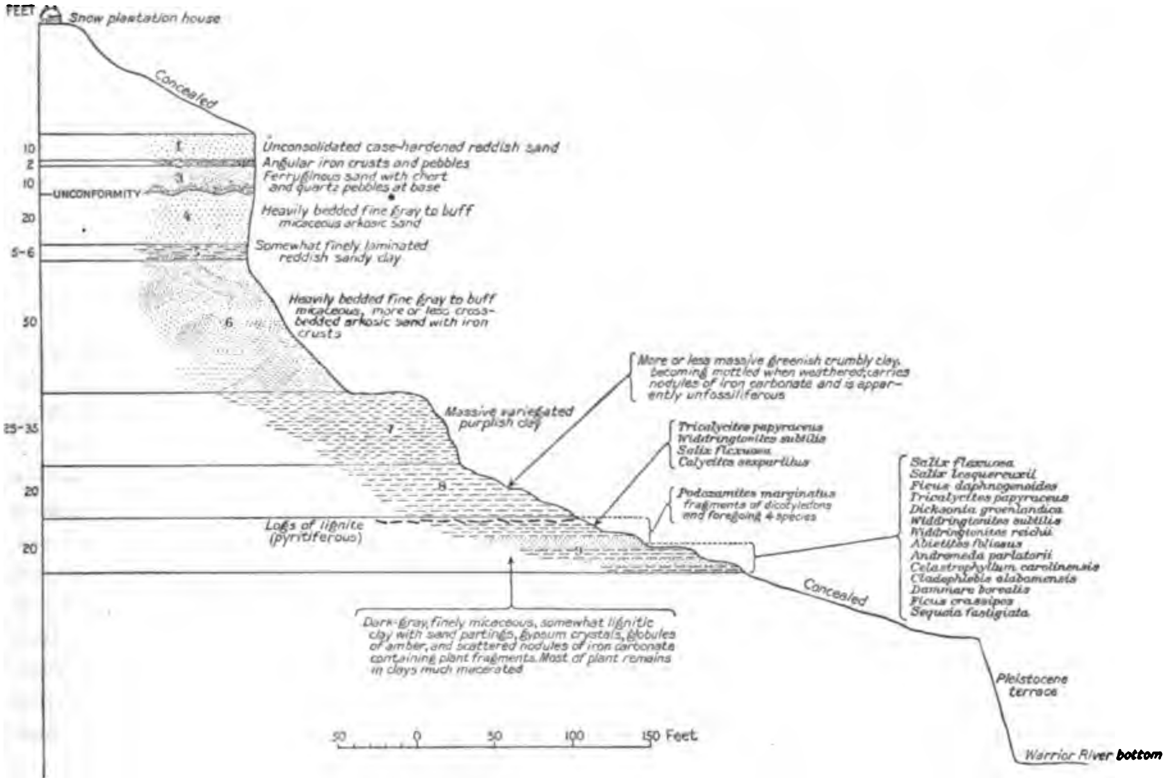

FEET
Snow plantation house
Concealed
10
2
10
UNCONFORMITY
20
5-6
50
25-35
20
20
1
3
4
6
7
8
9
Unconsolidated case-hardened reddish sand
Angular iron crusts and pebbles
Ferruginous sand with chert and quartz pebbles at base
Heavily bedded fine gray to buff micaceous arkosic sand
Somewhat finely laminated reddish sandy clay
Heavily bedded fine gray to buff micaceous, more or less cross-bedded arkosic sand with iron crusts
Massive variegated purplish clay
More or less massive greenish crumbly clay, becoming mottled when weathered; carries nodules of iron carbonate and is apparently unfossiliferous
Tricalycites papyraceus
Widdringtonites subtilis
Salix flexuosa
Calycites saxparilius
Podozamites marginatus
fragments of dicotyledons and foregoing 4 species
Logs of lignite (pyritiferous)
Salix flexuosa
Salix lesquereuxii
Ficus daphnogenoides
Tricalycites papyraceus
Dicksonia groenlandica
Widdringtonites subtilis
Widdringtonites reichii
Abietites foliosus
Andromeda parlatorii
Celastrophyllum carolinensis
Cladophlebis alabamensis
Dammara borealis
Ficus crassipes
Sequoia fastigiata
Concealed
Dark-gray, finely micaceous, somewhat lignitic clay with sand partings, gypsum crystals, globules of amber, and scattered nodules of iron carbonate containing plant fragments. Most of plant remains in clays much macerated
Pleistocene terrace
Warrior River bottom
50 0 50 100 150 Feet

FIGURE 4.—Section of the Tuscaloosa formation in an exposure in a gully on the Snow plantation, 9 miles southwest of Tuscaloosa, Ala.

This list and that from Glen Allen and Shirleys Mill together contain 131 species of the known flora of the Tuscaloosa, which numbers 151 species, and although this combined list includes many forms which range through the entire thickness of the Tuscaloosa and into the basal beds of the Eutaw it also contains a number of distinctive forms and as a whole may be considered as giving a representative picture of the flora which clothed the southern Appalachian land area at the time that Tuscaloosa sedimentation began.

SNOW PLANTATION NEAR TUSCALOOSA, ALA.

Two outcrops on the Snow plantation on the west bank of Black Warrior River, about 9 miles southwest of Tuscaloosa, have yielded many fossil plants, extensive collections having been made from them in 1887 by Fontaine and smaller collections by Berry and Stephenson in 1909. These outcrops are referred to on the labels as "Upper ravine" and "Big gully, Snow place." Erosion has eaten into the upland along the west bank of the river and the largest gully, which shows the following noteworthy section, is known locally as Catamount Bluff. There is an almost sheer drop of nearly 100 feet at the head of the gully and its top is about 300 feet above the bottom land of Black Warrior River. The section is shown diagrammatically in figure 4. It differs from the other sections reproduced in several particulars. The plant remains are much macerated, but the bedding throughout is principally massive and cross-bedding is not prominent. The upper sands carry many arkosic grains, and there is much secondary gypsum disseminated through the clays. No extensive ferruginous ledges are developed and all of the materials are unlithified, but iron is abundant in the form of oxide, sulphide, and carbonate. Nodules of the carbonate containing vegetable matter were found. Fossil plants occur throughout the basal 20 feet of the exposure, being most plentiful in the basal 10 feet, where the clays are somewhat lignitic and carry globules of amber. Above this point there is an interval of about 10 feet in which *Podozamites* leaflets greatly predominate, associated with a single gymnosperm and two or three species of dicotyledons. At this level (20 feet above the base) lies a pyritiferous clay stratum filled with large prostrate lignified logs above which the clays become more massive and apparently unfossiliferous. Twenty-six species have been identified from this outcrop and four from the near-by "upper ravine," where they come from the same horizon. These sections are between 300 and 400 feet above the base of the Tuscaloosa, and yet it was the Fontaine collections from here that suggested that the Tuscaloosa was perhaps Lower Cretaceous. The only forms suggesting a Lower Cretaceous age are *Abietites foliosus* and *Sequoia ambigua.* The latter occurs in both the Eutaw and Magothy formations and the former is associated at this outcrop with *Dryopterites stephensoni,* which was described from the much younger Ripley formation in Georgia. Although 13 or 14 species of this level are common to the basal beds, no traces of *Abietites* have been found in the latter, either here or at other localities. Seven of the species survive into the Eutaw but these are wide-ranging forms. Among them *Ficus crassipes* tends to synchronize the leaf-bearing horizon in this section with the post-Raritan of the Middle Atlantic Coastal Plain. Combining the species listed from the upper ravine with those from the Big Gully we have the following 30 forms from this locality:

Abietites foliosus (Fontaine) Berry.
Andromeda grandifolia Berry.
Andromeda novaecaesareae Hollick.
Andromeda parlatorii Heer.
Calycites sexpartitus Berry.
Carpolithus tuscaloosensis Berry.
Celastrophyllum carolinensis Berry.
    crenatum Heer.
Cladophlebis alabamensis Berry.
Dammara borealis Heer.
Dicksonia groenlandica Heer.
Dryopterites stephensoni Berry.
Eucalyptus geinitzi (Heer) Heer.
    latifolia Hollick.
Equisetum? sp.
Ficus crassipes (Heer) Heer.
    daphnogenoides (Heer) Berry.
    krausiana Heer.
Laurophyllum angustifolium Newberry?
Myrica emarginata Heer.
Myrsine borealis Heer.
Podozamites marginatus Heer.
Salix flexuosus Newberry.
    lesquereuxii Berry.
Sequoia ambigua Heer.
    fastigiata (Sternberg) Heer.
    reichenbachi (Geinitz) Heer.
Tricalycites papyraceus Newberry.
Widdringtonites reichii (Ettingshausen) Heer.
    subtilis Heer.

SANDERS FERRY BLUFF, ALA.

This notable exposure is formed by the next meander of Black Warrior River below the preceding section. It is about 2 miles farther southwest of Tuscaloosa by air line but of course much farther by the river. The section is remarkable for its predominantly argillaceous character, the only sand seen being at the base, where there is about 15 feet of cross-bedded, somewhat glauconitic sand. A stratum 38 feet thick begins about 40 feet above the base of the section and is made up of extremely compact, thinly laminated clay with partings of micaceous glauconitic sand. Near the middle of the stratum there is an abundance of disseminated needles of gypsum which I regard as primary, and toward the top leaves with their cuticles preserved are common. The following five species have been identified: *Acerates amboyensis* Berry, *Ficus crassipes* (Heer) Heer, *Ficus krausiana* Heer, *Salix flexuosa* Newberry, and *Salix lesquereuxii* Berry. All but the first of these also occur in the outcrops on the Snow plantation.

Above the fossiliferous stratum there is about 50 feet of massively bedded unfossiliferous clay. The section is shown diagrammatically in figure 5.

WHITES BLUFF, ALA.

Whites Bluff is in the northeastern part of Greene County, on the right bank of Black Warrior River, 309 miles above Mobile.

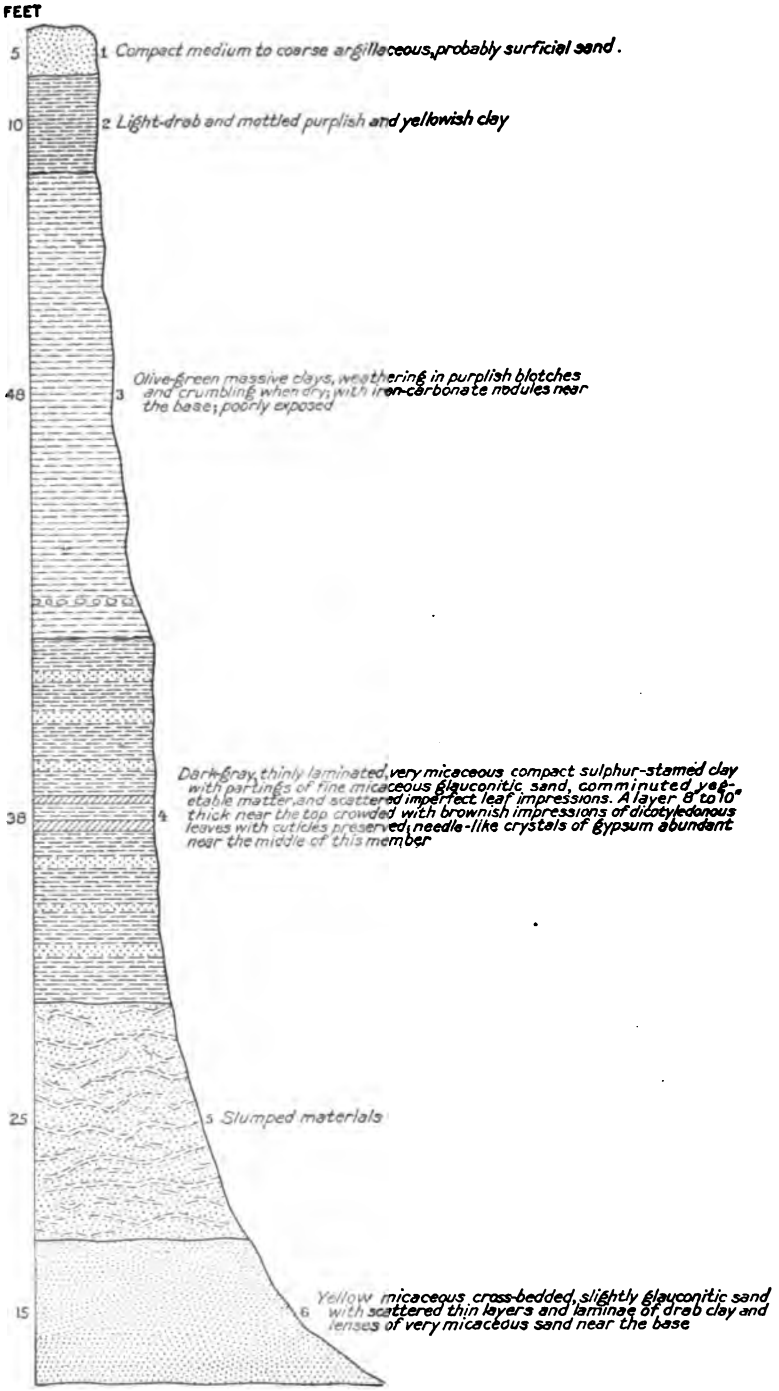

FEET
5
10
48
38
25
15
1 Compact medium to coarse argillaceous, probably surficial sand.
2 Light-drab and mottled purplish and yellowish clay
3 Olive-green massive clays, weathering in purplish blotches and crumbling when dry; with iron-carbonate nodules near the base; poorly exposed
4 Dark-gray, thinly laminated, very micaceous compact sulphur-stamed clay with partings of fine micaceous glauconitic sand, comminuted vegetable matter, and scattered imperfect leaf impressions. A layer 8" to 10" thick near the top crowded with brownish impressions of dicotyledonous leaves with cuticles preserved; needle-like crystals of gypsum abundant near the middle of this member
5 Slumped materials
6 Yellow micaceous cross-bedded, slightly glauconitic sand with scattered thin layers and laminae of drab clay and lenses of very micaceous sand near the base

FIGURE 5.—Section of the Tuscaloosa formation in an exposure at Sanders Ferry Bluff, on Black Warrior River, 12 miles below Tuscaloosa, Ala.

The outcrop is very near the top of the Tuscaloosa and fortunately it carries fossil plants, although they are neither abundant nor varied. The section is shown diagrammatically in figure 6. The materials are variable horizontally, the only persistent stratum being the 27 feet of blotched sandy, massive clay at the base. (See Pl. II, *B*, p. 14.) The following plants have been identified from this outcrop:

- Brachyphyllum macrocarpum formosum Berry.
- Dewalquea smithi Berry.
- Salix flexuosa Newberry.
- Sequoia heterophylla Velenovsky.
  - reichenbachi (Geinitz) Heer.
- Widdringtonites reichii (Ettingshausen) Heer.

All these plants occur in the basal part of the Tuscaloosa and all except *Sequoia heterophylla* and *Widdringtonites reichii* are common in the overlying Eutaw. The most remarkable form is the abundant *Dewalquea smithi*, which occurs also in the Middendorf arkose member of the Black Creek formation of South Carolina.

None of these plants can be regarded as distinctly Eutaw species, and they serve to emphasize the fact that the flora shows but slight changes from the base to the top of the Tuscaloosa.

The flora is thus about as well represented as that of the Raritan formation or the Magothy formation, with both of which it agrees in its general facies and the types of plants represented. The Tuscaloosa flora therefore presents nothing especially new, the forms represented being just such types as in general might be expected to occur in a flora of this age. There are some new forms that may reflect its more southern position, but I imagine these are really explained by the more careful comparisons instituted with the existing flora of tropical and subtropical America and fortified by a prolonged study of the subtropical floras of our Gulf Tertiary.

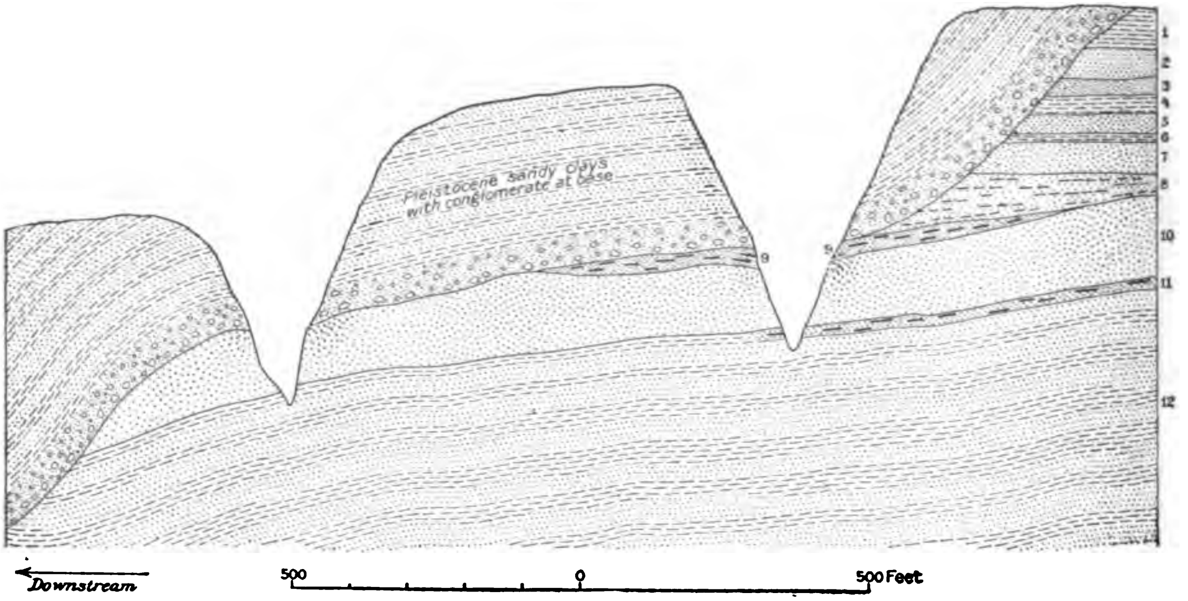


FIGURE 6.—Section of the Tuscaloosa formation in an exposure at Whites Bluff, Black Warrior River, 52¾ miles below Tuscaloosa, Ala. 1, Finely micaceous and arenaceous reddish and purplish blotched clays, 4 feet; 2, light-drab, finely micaceous and argillaceous laminated sand, 3 feet 3, greenish-gray fine micaceous massive sand, 2½ feet; 4, gray, finely arenaceous clay, 2 feet; 5, greenish-gray fine micaceous massive sand, 2 feet; 6, gray arenaceous massive clay, 1 foot; 7, greenish-gray compact micaceous massive argillaceous sand, 3 feet; 8, blotched purplish massive sandy ferruginous clay, 2½ feet; 9, very argillaceous sand with leaf impressions, lignite (some specimens bored by the teredo, *Feistmantellia*), and amber, a thin film to 2 feet; 10, greenish-gray or yellow, compact fine sand, 8 feet; 11, coarse gray sand and drab clay with lignite, leaf fragments, and amber, 1 foot: 12, purplish-blotched massive sandy clay, 27 feet.

COMPOSITION, ORIGIN, AND EVOLUTION OF THE TUSCALOOSA FLORA.

The Tuscaloosa flora as described in the systematic chapter embraces 151 species. The present treatment is conservative, as a considerable number of additional forms represented in the collections by incomplete material have been left uncharacterized. Unidentifiable seeds representing about a score of forms are also in the collections. Later, when the area in which the Tuscaloosa outcrops shall have been examined in detail, doubtless many new forms will be brought to light.

The 151 described species from the Tuscaloosa formation represent 87 genera, of which the following are not represented in existing floras: *Sphaerites*, *Jungermannites*, *Lycopodites*, *Cladophlebis*, *Dryopterites*, *Podozamites*, *Cycadinocarpus*, *Cephalotaxospermum*, *Protophyllocladus*, *Brachyphyllum*, *Protodammara*, *Geinitzia*, *Androvettia*, *Abietites*, *Widdringtonites*, *Cyperacites*, *Sabalites*, *Piperites*, *Populites*, *Proteoides*, *Dewalquea*, *Menispermites*, *Laurophyllum*, *Capparites*, *Palaeocassia*, *Phaseolites*, *Lirio-*

dendropsis, *Leguminosites*, *Citrophyllum*, *Crotonophyllum*, *Manihotites*, *Celastrophyllum*, *Cissites*, *Eorhamnidium*, *Grewiopsis*, *Pterospermites*, *Conocarpites*, *Cornophyllum*, *Dermatophyllites*, *Sapotacites*, *Tricalycites*, *Calycites*, *Carpolithus*, and *Phyllites*.

Thus 44 genera, or about half of the entire number described, are not represented, but it should be remembered that many of these are form genera, like *Laurophyllum*, *Capparites*, and *Leguminosites*, that reflect our ignorance of the exact affinities of the plants discussed. All the species are of course extinct, none surviving in the abundant lower Eocene floras of the Mississippi embayment. Many of the genera, however, are represented in the Eocene, the striking difference, in addition to the great modernization of the Eocene forms, being the dropping out of the Mesozoic gymnospermous types like *Androvettia*, *Abietites*, *Brachyphyllum*, *Protophyllocladus*, *Widdringtonites*, *Podozamites*, *Protodammara*, and *Geinitzia*.

The 87 genera represented are segregated into 48 families in 31 orders, the most abundant orders being the Ranales with 15 species, the Rosales with 15, the Sapindales with 15, the Coniferales with 14, and the Urticales with 8. The largest single genera are *Celastrophyllum* with 12 species, *Magnolia* with 8, and *Ficus* with 8. The additional genera that are represented by more than 2 species are *Myrica*, *Salix*, *Cocculus*, *Malapoenna*, *Bauhinia*, *Liriodendropsis*, *Diospyros*, and *Sapotacites* with 3 each, and *Sequoia*, *Leguminosites*, and *Andromeda* with 4 each.

In common with most Upper Cretaceous and later floras the bulk of the flora is made up of seed plants (Spermatophyta) and a large majority of these are dicotyledonous angiosperms.

The three numerically great modern phyla, the Thallophyta, Bryophyta, and Pteridophyta, are represented by only 11 recognizable forms, the first by a single species of leaf-spot fungus, the second by an inconclusively identified foliose liverwort, and the third by a single fragment of an *Equisetum*, two lycopodiaceous species, and six species of ferns. The Pteridophyta, which are so abundant in earlier floras, constituting about 30 per cent of the whole flora of the Potomac group of the Atlantic Coastal Plain, had dwindled to a meager 4 per cent in the Tuscaloosa flora, although they are somewhat more abundant in the nearly contemporaneous flora of the Atane beds of West Greenland, where they constitute 11 per cent of the known flora. Three species are referred to the family Polypodiaceae, a doubtfully determined *Marattia*, a *Dicksonia*, and a *Gleichenia* first recorded in the Lower Cretaceous of Greenland. If this *Gleichenia* originated in Greenland it must have covered more than 3,000 miles between the Nugsuak Peninsula (West Greenland) and Alabama in the interval between the Barremian and the Cenomanian, a period represented by the Aptian and Albian stages of European geology, during which this widespread species also reached Bohemia in Central Europe. *Asplenium dicksonianum* Heer and the two coniferous species, *Sequoia ambigua* and *Sequoia reichenbachii*, have a like distribution, but the *Sequoias* are both present in the Lower Cretaceous floras of Maryland and Virginia. The Gleicheniaceae are more abundant in most of the Upper Cretaceous floras than they are in the Tuscaloosa and still survive in tropical America.

Cycad-like plants, so abundant in Lower Cretaceous and older Mesozoic floras, are represented by a single species of *Podozamites*, on the assumption that *Podozamites* is really cycadaceous—an assumption questioned by many students. It is individually very abundant at the two localities in the Tuscaloosa where it has been found, and is another type whose range extends northward to Greenland. A second cycadaceous type is represented by the fruits referred to *Cycadinocarpus*, which are of rare occurrence in the Tuscaloosa deposits. Six species of Cycadophytes have been recorded from the Raritan formation of New Jersey.

The Coniferales of the Tuscaloosa flora are of exceptional interest, although they are represented by only 14 species as against 16 in the Raritan flora of New Jersey. They include modern types of *Pinus*, *Dammara*, and *Sequoia*, and the curious extinct phylloclad type *Androvettia*, as well as *Protophyllocladus*, *Brachyphyllum*, *Protodammara*, and *Geinitzia*. A species of *Abietites* survives from the Lower Cretaceous and represents an early abietineous form with a large and indeterminate number of leaves in each fasicle. Two species of *Widdringtonites* are abundant, one being represented by characteristic fruits. They are wide-ranging, almost cosmopolitan types in the earlier part of the Upper Cretaceous. The genus *Moriconia*, so characteristic and abundant in the Upper Cretaceous floras of the Atlantic Coastal Plain from Marthas Vineyard to South Carolina and found also in Greenland and western Europe at this time, is conspicuously absent in the Tuscaloosa flora.

Only three of the Coniferales appear to have survived into the overlying Eutaw deposits and these are all wide-ranging and persistent forms.

The angiosperms constitute the major part of the Tuscaloosa flora in common with all known Upper Cretaceous floras. It may be noted that the monocotyledons are represented by a single fragmentary and rare grass-like form referred to the form genus *Cyperacites*. There are many excellent reasons for the derivation of the monocotyledons from the dicotyledons, but on account of the scarcity of monocotyledons in fossil floras little light is thrown on the subject by paleobotanic studies. This scarcity of monocotyledons is largely due to the fact that the lack of differentiation of their foliage into lamina and petiole precludes the regular shedding of their leaves, which therefore hang on and are flayed by the wind until they become almost unrecognizable. This fact is well illustrated by their unimportant place in the subtropical floras of the early Tertiary in the Gulf region, where they must have been abundant but are only represented by forms like the palms and cannas, in which the leaves are differentiated into blade and stalk, and even the coriaceous-leafed palms are commonly represented by deposits packed with masses of frayed and detached rays.

The Dicotyledonae of the Tuscaloosa number 123 species, well distributed among 34 still existing families in 21 still existing orders. As might be expected, 107 of the dicotyledonous plants belong to the division Choripetalae and only 16 are referred to the essentially later and more specialized Gamopetalae. Of the forms referred to the Choripetalae 24 belong to the more or less artificial group of Apetalae and 77 to the Polypetalae. Ten species are referred to the so-called amentiferous families.

The order Ranales, which includes 15 species, has one supposed species of Ranunculaceae referred to the genus *Dewalquea*. This species is represented in abundance by satisfactory remains and constitutes a curious type which appeared with apparent suddenness in the Atane beds of Greenland, the Raritan formation of New Jersey, the Tuscaloosa formation of Alabama, and the Cenomanian of Bohemia, survived in some of these areas through the remainder of the Upper Cretaceous, and was last seen in the Paleocene of western Europe.

The Ranales include 9 species of Magnoliaceae, perhaps unduly enlarged by a too great differentiation of the leaves referred to *Magnolia*, and 5 species of Menispermaceae.

The prominence of the orders Rosales and Sapindales is explained largely by the fact that so many of their species are coastal types, which stand a much better chance of preservation than do forms of other habitats. In many ways the most interesting plants in the order Rosales are the striking new species of *Hymenaea* and the two diverse species of *Bauhinia*, a genus which in the existing flora is an inhabitant of the Tropics. Its curious bilobate, butterfly-like leaves are very characteristic in both their outline and venation and could scarcely be confused with any other type. The large Tuscaloosa form occurs also in the Raritan formation of New Jersey and the small form is found in the Magothy formation of Maryland. Three species of *Liriodendropsis* are referred to the family Papilionaceae. The chief genus of the Sapindales, as these forms are usually interpreted, is *Celastrophyllum*, which has 13 forms in the Tuscaloosa flora. *Celastrophyllum* makes a remarkable display in the late Lower Cretaceous (Patapsco formation) of the Atlantic Coastal Plain, and the Tuscaloosa shares with the Raritan and Dakota in an abundant and varied display of forms, not one of which is known to survive in the overlying Eutaw deposits. Similarly none are found in the deposits of the Montana group in the Rocky Mountain province, but two or three survive Raritan time and occur in the Magothy formation of the New Jersey-Maryland area and in the Black Creek formation of the Carolinas.

The order Urticales has 8 species, all referred to the genus *Ficus* of the family Moraceae, and most of them are very abundant individually. Both the palmate and pinnately veined types are represented, most of the species being widely distributed and largely coastal forms, which, combined with the coriaceous nature of the leaves of many of the species, explains their abundance in all fossil floras that flourished where the climate was not intolerant.

The order Proteales, no longer represented in North America and largely antipodean in the existing flora, is represented by a species of *Proteoides* and two species of *Persoonia*. It is thus somewhat less prominent than in most Upper Cretaceous floras.

The remaining elements in the flora need not be enumerated in the present connection, as they would contribute nothing of especial significance to the discussion.

The origin of this flora, particularly of its large dicotyledonous element, is one of surpassing interest to both the geologist and botanist. The place and manner of evolution of this type of plant, which so quickly replaced all others in the struggle for possession of the soil, are still uncertain. They appear with apparent suddenness at the close of the Lower Cretaceous in America, Europe, and the Arctic region. Like so many other plant and animal types, they must have had a long antecedent period of evolution, extending back, perhaps, well into the Jurassic. The fact that so many of them, and a number of them forms of identical species, are first recorded at about the same time in Greenland, North America, and Europe is capable of several interpretations. The late Lower and early Upper Cretaceous floras of Asia are practically unknown, and it is quite possible that Asia was the theater of their evolution, from which continent they may have spread eastward into North America and westward into Europe. It seems to be established that they were more abundant in America than in Europe during the earlier recorded stages of their history, and there are quite a number of forms whose appearance in North America seems to have preceded their appearance in Europe by an appreciable though slight time interval. This suggests that North America was nearer their center of radiation. I do not regard the Southern Hemisphere as at all likely to have been their original home. I have plotted the Mesozoic and Cenozoic distribution of a large number of the genera, and there is always a consistent progressive southward migration.

Theoretically the eastern part of North America, during the long interval of emergence and erosion covered by the Jurassic period, offers many potential possibilities. North America may have been the original home of the Mesozoic and Cenozoic floras, but this is not substantiated by the records, and our records of the Mesozoic land flora are far more representative and complete at the present time than those of any other country. At present there is absolutely no evidence of their having originated in the European area. A remaining alternative is that of regarding the Arctic area as the scene of their evolution and dispersal. This theme has been dwelt upon by more than one student of both floras and terrestrial faunas. The facts available, though suggestive, are not conclusive, but thus far they are more in accord with the theory of Arctic origin than with any others, so that at least tentatively we may picture successive waves of migration sweeping southward from the North Polar region during the late Lower and early Upper Cretaceous. The Upper Cretaceous floras indicate somewhat cooler climatic conditions than those of the Lower Cretaceous, and these conditions may have been a prominent factor in causing such migrations.

These floras show but slight evidence of rapid generic evolution during the Upper Cretaceous, although specific evolution seems to have been accentuated at times. The records, however, fail to show any large number of synthetic types, most of the generic types being well differentiated from the beginning of the record down to the present time. A more or less well defined change in facies separates the Cenomanian from the Turonian and Senonian floras, but this change seems to be largely a reflection of migrations which are but little understood and which are due to changes in habitat and climate rather than to evolutionary processes. The principal types were chiefly long lived and wide ranging, and there are many single forms which are found from West Greenland to Alabama and extend chronologically from the base of the Raritan through the Tuscaloosa into the basal beds of the Eutaw. The first appearance of some of these types in the upper part of the Lower Cretaceous suggests a longer time interval, but they are too few to be relatively significant.

ECOLOGIC CONDITIONS INDICATED BY THE TUSCALOOSA FLORA.

Any attempt to reconstruct the details of the physical conditions under which the Tuscaloosa flora flourished is beset with the greatest uncertainties. The flora is not only too remote from the present time for accurate comparisons, but exact knowledge of the finer reactions of recent plants to their environment is lacking, and most of the current ideas on this subject are largely empirical. In all but desert areas the interrelation of diverse factors is almost infinitely complex.

Some general statements, however, can be deduced, and from a study of the sediments and the present topography of this and adjoining areas we can get a more or less accurate even if faint picture of the physical geography of the Tuscaloosa time.

During the enormous interval of time represented in other parts of the world by marine sediments of Pennsylvanian, Permian, Triassic, Jurassic, and Lower Cretaceous age the southern Appalachian region was above sea level. Physiographically the southern half of this region is segregated at the present time into the Piedmont Plateau, the Appalachian Mountains (which die out in northwestern Georgia), the Appalachian Valley, the Cumberland Plateau, and the Interior Lowlands. Its area south of Ohio River is over 160,000 square miles and the actual area of this land mass during the interval from the Carboniferous to the Upper Cretaceous must have been very much greater than this, for nowhere along the margins of this massif have marine sediments of these ages been deposited near enough to its present limits to be reached by deep borings near the margin of the present Coastal Plain.

The region of the southern Appalachians has long interested physiographers. Hayes and Campbell, the chief contributors,[1] have recognized three base-levels or peneplains, which they term in the order of their age the Cumberland, the Highland Rim, and the Coosa. They consider that the original Tennessee River, which they term Appalachian River, flowed southwestward by way of the valley of Coosa River throughout the Upper Cretaceous and the major portion of the Tertiary until it was diverted by stream capture due to the working back across Walden Ridge of a stream in the Sequatchie Valley to the west of that ridge. This spectacular river capture has been disputed by Johnson,[2] who, it seems to me, conclusively demonstrates that the present course of Tennessee River across Walden Ridge in a winding gorge is imposed from meanders inherited from the period of earliest complete base-leveling in this area, namely, from the Cumberland peneplain.

The character of the Upper Cretaceous sediments of the eastern Gulf area throws considerable light on the physical history which has interested me chiefly in connection with the interpretation, in terms of geologic history, of the extensive fossil floras that have been found in the earliest Upper Cretaceous or Tuscaloosa formation of this region.

The Tuscaloosa formation in the area around Tuscaloosa, Ala., and for some distance to the northwest consists of a great thickness of predominantly sandy materials which give the country its present broken topography. These sands are generally light in color, cross-bedded and micaceous; in some places there are traces of glauconitic layers. There are heavy beds of gravel made up of well-rounded quartz and subangular chert pebbles in about equal proportions in places, especially toward the landward margin of the deposits and northward along the strike. In disconnected and interbedded lenses there is a considerable amount of argillaceous material—locally massive or heavy bedded but generally laminated. Thin seams of lignite are present at various levels, but these are generally only a few inches or less in thickness. The clays are commonly oxidized and mottled in color, but they are as commonly very carbonaceous and dark in color. In some sections, as in the section in the Big Gully southwest of the town of Tuscaloosa, there are layers filled with prostrate logs of trees of large size. Pyrite and ferruginous oxide, forming locally indurated sandstones and gravels, are generally distributed, and finely disseminated crystals of gypsum are very common.

No fossils other than the remains of land plants have been found in the Tuscaloosa deposits. Usually the plant remains are much macerated and broken by water transportation and deposited in films of broken fragments in the laminated beds. Drift logs are common, and these occasionally brought down cobbles embedded in their roots, as is shown by specimens of lignitized tree roots that have been collected. There appear to have been areas of quiet waters at certain localities where the leaf remains in the clays are abundant and in a state of preservation indicating that they grew in the immediate vicinity.

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[1] Hayes, C. W., and Campbell, M. R., The geomorphology of the southern Appalachians: Nat. Geog. Mag., vol. 6, pp. 63–126, 1894. Hayes, C. W., The physiography of the Chattanooga district: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, pp. 1–58, 1899.

[2] Johnson, D. W., The Tertiary history of the Tennessee River: Jour. Geology, vol. 13, pp. 194–231, 1905.

The outcrop of the Tuscaloosa formation, as shown in the sketch map (fig. 7), is roughly lunate in outline with the southeastern horn terminating near Montgomery, Ala., and the other extending as an attenuated band across western Tennessee. As shown in the sketch map, the greatest width of outcrop coincides with the maximum thickness of sediments in a belt about 125 miles in length which is at right angles to the axis of the Appalachian land mass. Toward the north the deposits become thinner, are prevailingly gravels, and are shown by the fossil plants to be somewhat younger than the main body of the deposits.

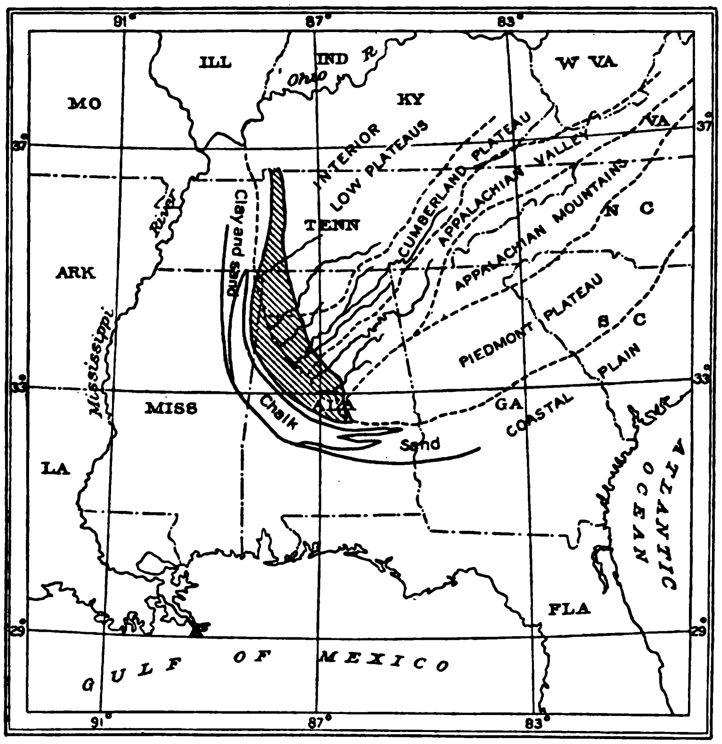

FIGURE 7.—Sketch map showing the Tuscaloosa drainage and its subsequent history.

The delta-like character of the Tuscaloosa deposits, with their gravels and compound oblique cross-bedded sands, their local traces of glauconite, and their abundance of driftwood, can not fail to be noticed. We are now fairly familiar with the main features of delta deposits in different parts of the world,[1] and Grabau[2] and Barrell[3] have recently made considerable contributions toward the interpretation of Paleozoic delta deposits. In the Tuscaloosa region no sediments later than the Pottsville were laid down until the deposition of the Tuscaloosa in the earlier Upper Cretaceous. This long interval resulted in the nearly complete base-level known as the Cumberland peneplain. There must have been some regional uplift or warping at the beginning of Tuscaloosa time to account for the sudden augmentation in river action and the beginning of the large delta or series of deltas along the southwestern margin of the land mass. There is no evidence in the sediments that an Appalachian river flowed southwestward through the Coosa Valley. Such a river would have brought the bulk of the sediments farther eastward than the region where they now occur. Though I regard Johnson's evidence [4] as conclusive for the course of Tennessee River across Walden Ridge, I can not help believing that the Cretaceous ancestor of this stream at the beginning of Tuscaloosa time, instead of making the sharp turn to the northwest at Guntersville, Ala., which it does at present, continued southwestward down either Brown or Big Spring valleys and reached the sea through either Mulberry or Locust Fork of Black Warrior River. This, however, is not an essential part of my argument for the delta character of the Tuscaloosa formation, for there was obviously at that time a stream or a series of streams draining to the southwest and engaged in removing the débris of the long-weathered land mass.

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[1] Credner, G. R., Die Deltas: Petermanns Mitt., Ergänzungsheft 56, pp. 1-74, pl. 3, 1878.

[2] Grabau, A. W., Early Paleozoic delta deposits of North America: Geol. Soc. America Bull., vol. 24, pp. 399-528, 1913.

[3] Barrell, Joseph, Geol. Soc. America Bull., vol. 23, pp. 377-446, 1912.

[4] Johnson, D. W., op. cit.

I do not ignore the fact that some of the Tuscaloosa deposits are subaerial and that originally the delta deposits probably continued inland up the valley or valleys for considerable distances as continental deposits of channels, flood plains, and lakes. The antecedent meanders of the present streams give clear evidence of conditions that prevailed on the Cumberland peneplain that were suitable for the formation of oxbow lakes. There must have been quiet waters in the delta itself in certain bayous or possibly lakes like Lakes Salvador, Pontchartrain, and Borgne of the present Mississippi Delta region. Certainly the leaf-bearing clays near Glen Allen and Shirleys Mill, in Fayette County, Ala., were formed in such quiet bodies of water with densely wooded shores.

that is, southwest of the axis of the Appalachian land mass. In this area the Selma chalk continues upward to the Eocene contact. Its outcrop, as shown in the sketch map (fig. 7), is almost perfectly lunate, and at its horns both to the east and the north it passes over into sands. The Selma, as shown by its abundance of Ostracea and other Mollusca, is a shallow-water deposit. So far as my observation goes, it is entirely destitute of driftwood, lignite, or any considerable sandy beds in the area of its greatest thickness, and I wish to make clear that the southwestern drainage, which explains the character of the Tuscaloosa sediments, must have been reduced to a minimum or become practically nonexistent before the deposition of the Selma chalk. The prevailing direction of the drainage during Selma time must have been to the southeast and northwest in order to account for the Ripley sands in those regions and the absence of any except the finest terrigenous materials in the main body of the Selma chalk.

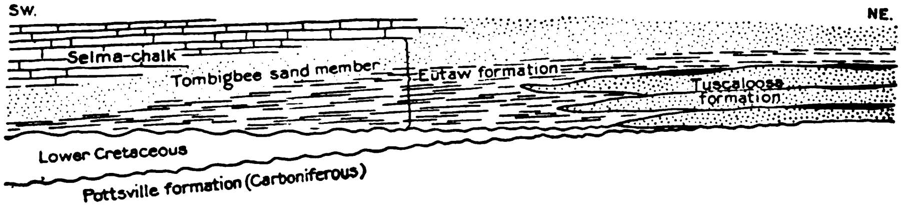

FIGURE 8.—Hypothetical section illustrating the interrelationship of the Upper Cretaceous types of sedimentation from Tuscaloosa to lower Selma.

The relations of the Tuscaloosa formation emphasize its delta character. (See figs. 7, 8.)

The Tuscaloosa sands grade seaward into the glauconitic sands and thinly laminated clays of the Eutaw formation, which contains a sparing representation of the marine life of the time and which must have been in part at least contemporaneous with the Tuscaloosa. A few plants in the near-shore transgressing phase have been collected from the vicinity of Havana, Hale County, Ala. The upper Eutaw, or Tombigbee sand member, I regard as a transgressing deposit, and in conformity with this interpretation it contains a much better marine fauna than the earlier Eutaw deposits. Overlying the Eutaw formation is the Selma chalk—an argillaceous limestone or calcareous clay, which reaches its maximum thickness in the same region as the Tuscaloosa sands—

Inferentially, if the Cretaceous Tennessee River was a factor in the building of the Tuscaloosa Delta, local warping must have broken its continuity with the Black Warrior drainage and started it toward the northwest before the deposition of the Selma chalk. It is possible that this may have been accomplished without local warping by the simple clogging of its distributaries as a result of their own loads combined with decreased run-off. This set of factors, combined with the westward tilting that resulted in the Ripley Cretaceous and Midway Eocene seas penetrating up the Mississippi Valley as far as southern Illinois, is sufficient to account for such a change in course. This change in the direction of the drainage may be compared to the shifting of the present Mississippi Delta toward the east by marine currents.

The remnants of heavy gravels of Tuscaloosa age that have been traced by Wade[1] across Tennessee and into Kentucky appear to represent the gradual migration or shifting northward of such a stream. That the western Highland Rim of Tennessee has resulted from a middle or late Tertiary planation of prevailingly siliceous rocks by Tennessee River in its lower northward course is probably true, but the discussion of this feature hardly falls within the scope of this paper.

A feature that makes the Tuscaloosa flora of especial interest is the fact that the plants whose fragmentary remains are preserved in the clays of the Tuscaloosa formation grew on soils derived from Paleozoic sediments, and that all of the heretofore known Cretaceous floras of the Coastal Plain grew on soils of the Piedmont type, which were derived from igneous or highly metamorphosed rocks, the only possible exception being the Raritan flora of New Jersey, which is in deposits resting directly upon the Triassic sandstones and shales. However, even the Raritan materials show no apparent evidence that these rocks contributed to the Raritan sediments, and the theory has been advanced that the only emerged Triassic rocks in Raritan time in the area of their development were diabase and basalt.

Plant geographers have long noticed the differences in the vegetation of areas of calcareous rocks and those of basic igneous rocks, but the laws governing these differences seem to be as yet unformulated. I can see nothing in the facies of the Tuscaloosa flora that can be attributed to the character of the soil. The flora is essentially the same familiar early Upper Cretaceous flora that is found in the late Raritan and in the Magothy formation from Marthas Vineyard to Potomac River, and that reappears in the earlier beds of the Black Creek formation in the Carolinas and in the Woodbine sand of Texas. Its essential elements are present in West Greenland and in Europe at Niederschoena, Saxony, in Bohemia, or wherever floras of this age have been preserved.

In general, the flora is of a lowland coastal type. The only plant, judging from its occurrence and condition of preservation, that may have come from a region removed from the coast is *Androvettia carolinensis*. I doubt very much if there remained at that time any considerable area of greatly elevated land in the southern Appalachian province. A number of the Tuscaloosa plants, judging by their modern relatives, were distinctly strand types. To this class probably belonged the myricas, the figs, and several of the Lauraceae, Leguminosae, and Celastraceae. The Sapindaceae and Rhamnaceae are also in general strand types. This seems to have been especially true of the genus *Eorhamnidium*, which clearly shows, not only in the Tuscaloosa flora but in the succeeding Tertiary, that its habits of growth are comparable with those of the monotypic existing genus *Krugeodendron* of the American tropical strand flora. The members of the Myrtales also were probably dwellers in the dry or wet strand, as are so many modern species of *Eugenia* and *Myrcia*. The supposed Ericaceae were probably strand types, and the Sapotaceae almost certainly were, as well as the genus *Conocarpites*.

With regard to the elements that made up the Tuscaloosa climate the data are not exact. It would seem from the coarseness of the sediments that the run-off was great. Many of the plants demand a heavy rainfall. This is also indicated by the development of the so-called dripping points in many unrelated Moraceae, Lauraceae, Leguminosae, Sapindaceae, and Ericaceae?. Several of these forms range northward to Greenland, and they become much more elongated and acuminate toward the southern limit of their range. Finally the mingling of types whose descendants characterize tropical and temperate climes is only paralleled by a similar mingling in those modern areas known as warm-temperate rain forests. Such areas as southern Japan or northern New Zealand offer many points of comparison with the Upper Cretaceous floras of the Coastal Plain, as I have insisted in several previous publications. With regard to actual temperatures during Tuscaloosa time, specific data can not be expected. The climate, to judge by modern standards, appears to have been cooler than that of the Lower Cretaceous. However, it should be remembered that the numerous cycadophytes and tree ferns of the Lower Cretaceous were the dominant types of the older Mesozoic, with a cosmopolitan range which, from numerous analogies, would be expected to have become adapted to a wide range of physical conditions. The flora of the Tuscaloosa is certainly less clearly indicative of tropical conditions than are some of our southern Tertiary floras. Among the Tuscaloosa plants whose modern representatives are strictly subtropical types I might mention the genera *Gleichenia*, *Piperites*, *Cocculus*, *Oreodaphne*, *Capparites*, *Inga*, *Bauhinia*, *Citrophyllum*, *Crotonophyllum*, *Sapindus*, *Grewiopsis*, *Zizyphus*, *Eorhamnidium*, *Pterospermites*, *Eugenia*, *Conocarpites*, *Myrsine*, *Sapotacites*, and *Cordia*.

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[1] Wade, B., Johns Hopkins Univ. Circ., March, 1917, pp. 102-106.

One feature that stands out very clearly is the manner in which this Upper Cretaceous flora preserves its integrity when traced northward. A comparison between the flora of Alabama and New Jersey shows but slight differences, and none which can be directly correlated with climatic conditions. Even when comparisons are made with such remote northern regions as Disko Island, in latitude 70° N., similar results are obtained, the difference of 38° of latitude being apparently of slight importance, the extreme northern area being much richer in ferns and cycadophytes than the extreme southern area and including such strictly tropical forms of the modern flora as *Artocarpus*, which is represented by both characteristic leaves and fruit in Greenland.

These considerations lead to the conclusion that Upper Cretaceous climate during Tuscaloosa time was much more uniform both secularly and seasonally over wide areas and was very different in this respect from modern climates. A consideration of all ancient climates based on floras and marine faunas of all ages unmistakably points to the conclusion that existing climates are exceptional, and that during the long history of the globe the rule has been one of comparatively uniform climatic conditions from the Equator to the Poles, with a lack of marked differentiation into seasons. At times of maximum land emergence climatic conditions have become diversified and more or less extensive glaciations have resulted, but these periods form a very small fraction of the total geologic time.

In conclusion it may be postulated that the Tuscaloosa flora occupied a low coastal land of rather uniform topography—a land favored with an abundant and well-distributed rainfall, with equable temperatures within the limits embraced between warm temperate and subtropical, and with slight seasonal changes.

EUTAW FORMATION.

HISTORICAL SKETCH.

The name Eutaw was proposed by Dr. E. W. Hilgard[1] in 1860 for deposits in northeastern Mississippi described as "bluish-black or reddish laminated clays, often lignitic, alternating with and usually overlaid by noneffervescent sand, mostly (though not always) poor in mica, and of a gray or yellow tint." The name was chosen because these beds were first studied and recognized as of Cretaceous age by Tuomey[2] near Eutaw, Ala., where they are typically developed.

Smith and Johnson,[3] in their study of the Alabama Coastal Plain, adopted the term Eutaw and extended its upper limits to include the Tombigbee sand of Hilgard, differentiating the Tuscaloosa below, the Mississippi representative of the Tuscaloosa being included in the Eutaw as the term was used by Hilgard. It is not worth while in a study of the floras to go into the details of the history of the study of these deposits but merely to state that the recent areal and faunal studies of L. W. Stephenson have shown that the Eutaw is represented in western Tennessee by the Coffee sands of Safford, as Glenn[4] announced in 1906. The history of the study of the flora of the Eutaw formation can be summed up in a single brief paragraph, for though different students mention lignite in the formation the only reference to leaf impressions is a line in Langdon's general section of Chattahoochee River, where, in referring to the outcrop at Chimney Bluff, he mentions, "Yellow sands and gray clay, containing bits of leaves."[5] The plant locality near Havana, in Hale County, Ala., was discovered by Prouty and Stephenson in 1908 and a small collection was made. This represents the only collection of the Eutaw flora prior to the present study, which is based on collections made by me in company with Stephenson in 1909, supplemented by later collections made by Bruce Wade.

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[1] Hilgard, E. W., Report on the geology and agriculture of Mississippi, pp. 61-68, 1860.

[2] Tuomey, Michael, Alabama Geol. Survey First Bienn. Rept., pp. 118-120, 1850.

[3] Smith, E. A., and Johnson, L. C., Tertiary and Cretaceous strata of the Tuscaloosa, Tombigbee, and Alabama rivers: U. S. Geol. Survey Bull. 43, pp. 71-136, 1887.

[4] Glenn, L. C., Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in Illinois: U. S. Geol. Survey Water-Supply Paper 164, p. 23, 1906.

[5] Smith, E. A., Langdon, D. W., jr., and Johnson, L. C., On the geology of the Coastal Plain of Alabama, p. 440, Alabama Geol. Survey, 1894.

A preliminary account[1] of the flora of the Eutaw in the Georgia area was published in 1910 and a complete account[2] has been published by the United States Geological Survey. Lists of plant species quoted from the preliminary account and from the manuscript of the completed report were given by Stephenson[3] in 1911.

AREAL DISTRIBUTION.

The Eutaw formation, consisting of sands, clays, and marls, outcrops in a belt of varying width extending from Taylor County, in western Georgia, to the southern part of Benton County, in western Tennessee, a distance between 400 and 450 miles. Scattered remnants containing *Halymenites* and found as far north as Trigg County, Ky., are believed to represent a former more northerly extent of this formation. Along Chattahoochee River this belt is about 10 miles wide, across Alabama it ranges from 5 to 15 miles, across northeastern Mississippi it is from 5 to 12 miles, and in western Tennessee it is from 2 to 8 miles, averaging somewhat less than 4 miles.

LITHOLOGIC CHARACTER.

The Eutaw is predominantly composed of sand, but the materials vary through wide limits. Along Chattahoochee River the base is an arkosic, micaceous sand with pebbles and small intercalated lenses of laminated carbonaceous and lignitic clay. The clays in places carry fossil plants and were apparently deposited in shallow marine waters. Overlying the basal bed, which is not very thick, is about 50 feet of typically marine, fine, more or less micaceous and calcareous fossiliferous sands and clays. Above this is several hundred feet of variable, mostly shallow-water materials. These are predominantly cross-bedded to massive micaceous sands and dark laminated lignitic clays. Overlying this material is about 120 feet of massive marine irregularly bedded sands and clays, constituting the Tombigbee sand member (included by Langdon in the Ripley and forming a part of the Blufftown marl of Veatch). All the fossil plants come from the beds below the Tombigbee sand member. In passing eastward from Chattahoochee River even the Tombigbee member of the Eutaw becomes littoral in character, the materials being progressively coarser and more irregularly bedded.

In western Alabama the Eutaw materials are exceedingly variable and are predominantly sands. The sands are light colored and much cross-bedded and are interbedded with thinly laminated dark clays, strongly suggestive of the similar laminated clays of the Black Creek formation of the Carolinas. None of the lower beds of the Eutaw are persistent for any distance, but the upper calcareous Tombigbee sand preserves its identity fairly well across the State. A similar variable lithology characterizes the Eutaw across northeastern Mississippi and in western Tennessee.

The strike of the Eutaw is northeast in Georgia; it becomes more nearly east across Alabama, turns to the northwest in the western part of the State, and gradually becomes north through most of its extent in Mississippi and in Tennessee. It dips between 20 and 30 feet to the mile. In its area of maximum development from Chattahoochee River westward across Alabama it is between 500 and 600 feet thick. The materials become coarser, and eastward in Georgia, where the deposits become thinner, they show increasing evidence of shallow-water deposition. In the northwestern part of its outcrop in Mississippi and Tennessee the Eutaw also becomes thinner, being there between 300 and 400 feet thick.

STRATIGRAPHIC RELATIONS.

In Georgia and eastern Alabama the Eutaw rests with a marked unconformity on the Lower Cretaceous. From Alabama River to the Mississippi-Tennessee boundary it rests without apparent unconformity on the Tuscaloosa. From the Tennessee boundary until it disappears, it overlies the Paleozoic rocks which constitute the floor of the embayment.

Except for the Pleistocene deposits, the Eutaw is overlain throughout its extent in eastern Alabama and in Georgia, without apparent unconformity, by the marine sands of the Ripley formation. From Macon County, Ala., westward and northward throughout its outcrop, it is overlain almost continuously by the Selma chalk. As I have explained elsewhere (p. 37), the Selma chalk is a lithologic and not a chronologic unit and represents, in the region of its maximum development, a part of the upper Eutaw and all of the Ripley.

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[1] Berry, E. W., Contributions to the Mesozoic flora of the Atlantic Coastal Plain; VI, Georgia: Torrey Bot. Club Bull., vol. 37, pp. 503-511, 1910.

[2] Berry, E. W., The Upper Cretaceous and Eocene floras of South Carolina and Georgia: U. S. Geol. Survey Prof. Paper 84, 200 pp., 1914.

[3] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, 466 pp., 1911.

LOCAL SECTIONS CONTAINING PLANT REMAINS.

Numerous local sections of the Eutaw formation have been published in recent years, to which the reader in search of details is referred, as only those few sections containing fossil plants will be discussed in this report.

McBRIDES FORD, GA.

About 11 miles southeast of Columbus, in Chattahoochee County, Ga., an interesting fossiliferous section discovered by Stephenson and visited by Stephenson and me, is exposed just above McBrides Ford on Upatoi Creek.

Section just above McBrides Ford, Ga.

	Feet.
Pleistocene:	
Sand with gravel at base, about	10
Unconformity.	
Eutaw formation (Upper Cretaceous):	
More or less pebbly, coarse cross-bedded sands with small lenses of lignitic carbonaceous clay, one of which contains the plants listed from this locality	10-15
Unconformity.	
Lower Cretaceous:	
Light-colored coarse arkosic sands	0-5

The leaf-bearing lens of almost black carbonaceous clay was only about 15 inches in maximum thickness and only a few feet in lateral extent. This lens and the other little clay lenses represent small shallow basins in the sandy bottom of the Eutaw sea that accumulated vegetable material drifted from the nearby shores. The following 19 species have been recognized from this clay lens:

Andromeda cretacea Lesquereux?
  wardiana Lesquereux.
Androvettia elegans Berry.
Aralia eutawensis Berry.
Brachyphyllum macrocarpum formosum Berry.
Cinnamomum heerii Lesquereux?
  newberryi Berry.
Eucalyptus angusta Velenovsky.
Ficus ovatifolia Berry.
Inga cretacea Lesquereux.
Magnolia boulayana Lesquereux.
  capellinii Heer.
Manihotites georgiana Berry.
Menispermites variabilis Berry.
Paliurus upatoiensis Berry.
Salix flexuosa Newberry.
Sequoia reichenbachi (Geinitz) Heer.
Tumion carolinianum Berry?
Zizyphus laurifolius Berry.

BROKEN ARROW BEND, GA.

At Broken Arrow Bend, on Chattahoochee River about 10½ miles below Columbus, good sections are exposed along both banks of the river. That containing plant remains is on the left bank in Chattahoochee County, Ga., about 100 yards below the section on the Alabama side. The following materials are exposed:

Section at Broken Arrow Bend, Ga.

	Feet.
Eutaw formation (basal beds):	
Gray calcareous micaceous sand with nodules of impure limestone, carrying a marine invertebrate fauna	15
Coarse cross-bedded sand, in part evidently reworked Lower Cretaceous materials with gravel and much lignite and thin lenses of compact dark-drab clay near the base carrying plant remains	2-15
Unconformity.	
Lower Cretaceous:	
Coarse gray arkosic cross-bedded sands with subordinate argillaceous materials	0-5

The fossil plants collected at this locality are few in number and much macerated and were evidently in the water some time before fossilization. The following species have been recognized:

Malapoenna horrellensis Berry.
Phragmites pratti Berry.
Salix eutawensis Berry.
Salix flexuosa Newberry.
Sequoia reichenbachi (Geinitz) Heer.

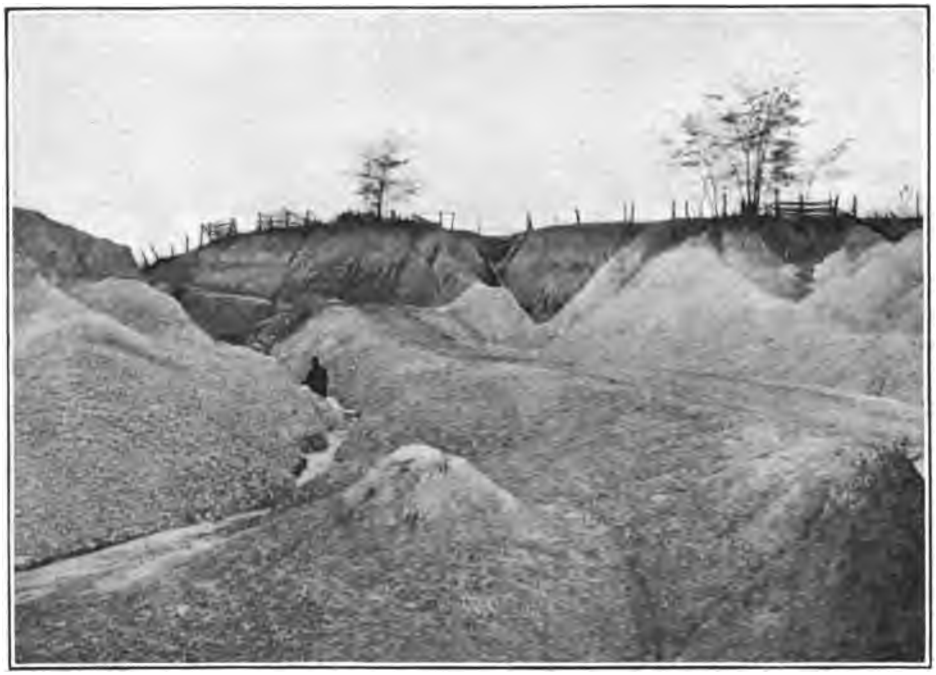
This is exactly the same horizon from which fossil plants were collected at McBrides Ford.

CHIMNEY BLUFF, GA.

At Chimney Bluff, on the left bank of Chattahoochee River, in Chattahoochee County, Ga., 22 miles below Columbus, the following section is exposed:

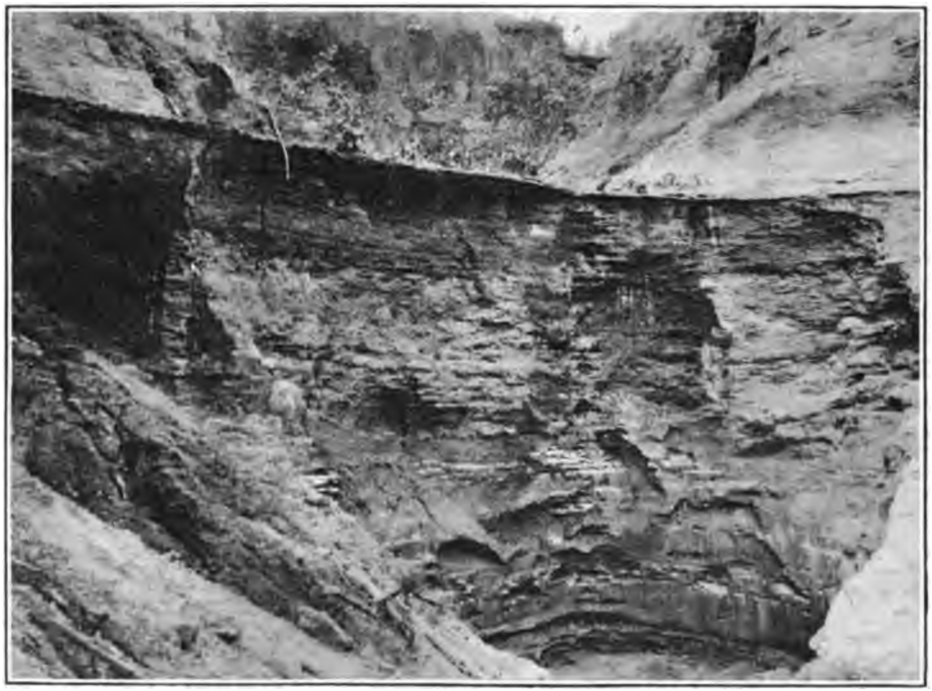
Section at Chimney Bluff, Ga.

	Feet.
Eutaw formation:	
Greenish (weathering yellowish) fine sandy clay with casts of marine invertebrates (Tombigbee sand member), about	50
Fine white loose, somewhat cross-bedded micaceous sand (lens), exposed	8-15
Irregularly bedded, laminated, cross-bedded, very lignitic pyritiferous sands and clay with pellets of amber and many large teredo-bored logs of lignite, the largest 2 or 3 feet in diameter, with small lenses of dark plastic clay carrying rather friable plant remains, about	25



A. VIEW SHOWING THE ARGILLACEOUS LEAF-BEARING SANDS OF THE RIPLEY FORMATION, 13 MILES NORTHWEST OF CAMDEN, TENN.

Photograph by L. W. Stephenson.



B. VIEW SHOWING THE CHARACTER OF THE BEDDING OF THE BASAL SANDS AND CLAYS OF THE EUTAW FORMATION, 2 MILES SOUTHEAST OF HAVANA, ALA.

Photograph by L. W. Stephenson.

The lower part of this section, which is in the lower part of the Eutaw, represents an accumulation of drifting vegetable matter and fine sediment behind some temporary bar or in some shallow water or eddy near the shore, possibly in the estuary of some Eutaw river. The plants show evidence of considerable immersion and transportation, only coriaceous forms which withstood maceration being in a recognizable condition.

The following species have been recognized:

Araucaria bladenensis Berry (leaf-bearing twigs).
  jeffreyi Berry (cone scales).
Ficus crassipes (Heer) Heer.
  krausiana Heer.
Salix flexuosa Newberry.
  lesquereuxii Berry.
Sequoia reichenbachi (Geinitz) Heer (twigs).

The most abundant form is *Araucaria bladenensis*, represented by some large foliage-bearing twigs and numerous detached leaves.

HAVANA, ALA.

Between 1½ and 2 miles southeast of Havana, in the north-central part of Hale County, Ala., extensive gullies have been eroded in the basal sands of the Eutaw formation. The lithology varies from gully to gully, and in only one have fossil plants been found. (See Pl. IV, *B*.) The section shown diagrammatically in figure 9 is exposed in this gully.

In common with the preceding Eutaw sections the fossil plants come from the basal beds of the formation. These basal sands and thinly laminated clays are more or less cross-bedded and carry considerable glauconite, which is perhaps the source of the numerous iron crusts. They are also micaceous and lignitic, carrying pellets of amber and much comminuted vegetable matter. The fossil plants are for the most part much macerated, some of the sand films between clay laminae being crowded with the detached leaves of *Sequoia reichenbachi*. The following 14 species have been identified from this outcrop:

Andromeda parlatorii Heer.
Araucaria bladenensis Berry.
Bauhinia alabamensis Berry.
  cretacea Newberry.
Brachyphyllum macrocarpum formosum Berry.
Cephalotaxospermum carolinianum Berry.
Diospyros primaeva Heer.
Doryanthites cretacea Berry.
Ficus krausiana Heer.
Laurus plutonia Heer.
Malapoenna horellensis Berry.
Myrcia havanensis Berry.
Sequoia ambigua Heer.
  reichenbachi (Geinitz) Heer.

The commonest form is *Araucaria bladenensis*. Next in abundance are *Doryanthites*, the two species of *Sequoia*, and the two coriaceous, lanceolate species of *Ficus*.

COFFEE BLUFF, TENN.

Coffee Bluff, which was described originally by Safford[1] in 1884, is on the west bank of Tennessee River in Hardin County, Tenn., and is the type locality of the Coffee sand, the uppermost member of the Eutaw formation. The river washes the bluff for nearly 2 miles, exposing the highly variable littoral materials that characterize the formation in this area. The following section is quoted from Glenn:[2]

Section at Coffee Bluff, Tenn.

	Feet.
1. Half a mile inland from the edge of the bluff, red and yellow chert gravels with overlying reddish sandy clay	15
2. Along descending slope of road to edge of bluff are poorly exposed light-colored sands and lead-colored clays interbedded in thin layers, which are usually minutely laminated	120
3. Top of bluff, light-colored sands similar in color, texture, and structure to those of the following member	12
4. Dark slate-colored clay in thin laminae, generally pure but in places has thin sandy layers; contains fragments of plants and locally shows an unconformity with the underlying beds	25
5. Fine gray sand interbedded with slaty or lead-colored clay in fissile papery laminae. The sand and clay are commonly interlaminated and more or less cross-bedded; in places a relatively pure bed of sand or clay several feet thick grades over along the bedding plane into the other within a few yards. On the surface of the thin fissile shales are leaf impressions. The sand and clay alike carry more or less lignitized wood, which is in small pieces except in the lower part of the bed, where logs of it are found. Decomposing pyrite is associated with the lignite. Two logs of petrified wood projected from this sand at the time Safford measured this section. In places a tendency to induration is noticeable in the sands, though generally they are rather soft. The cross-bedding is invariably on a small scale and frequent reversals of direction occur in many places.	40
6. Sand varying in color from light gray to canary yellow, micaceous	3
7. Sand, gray and lignitic, with much decomposing pyrite, to the water's edge	15

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[1] Safford, J. M., Am. Jour. Sci., 2d ser., vol. 37, pp. 360-372, 1864; Geology of Tennessee, p. 412, 1869.

[2] Glenn, L. C., U. S. Geol. Survey Water-Supply Paper 164, pp. 24-25, 1906.

Petrified wood collected by Wade from the beds included in No. 5 of the section represents a silicified species of *Cupressinoxylon* which is too poorly preserved for specific description. Pellets of amber are scattered in the lignitic clays, and one of these, discovered by Wade, contained the remains of an insect, which is, I believe, the first amber insect to be described from North America.[1] Fossil plants are not uncommon throughout the argillaceous portions of the section, but they are usually much broken and poorly preserved in the prevailingly sandy clays. During his mapping of Hardin County for the Tennessee Geological Survey, Wade made large collections of these plant fossils, which were referred to me, and the results of their study are incorporated in this report. A considerable portion of the collected material was too poorly preserved to be determinable, but a number of specimens, though most of them are fragmentary, have been satisfactorily identified. These are:

Andromeda wardiana Lesquereux.
    novaecaesareae Hollick.
Cinnamomum heeri Lesquereux.
Cupressinoxylon sp.

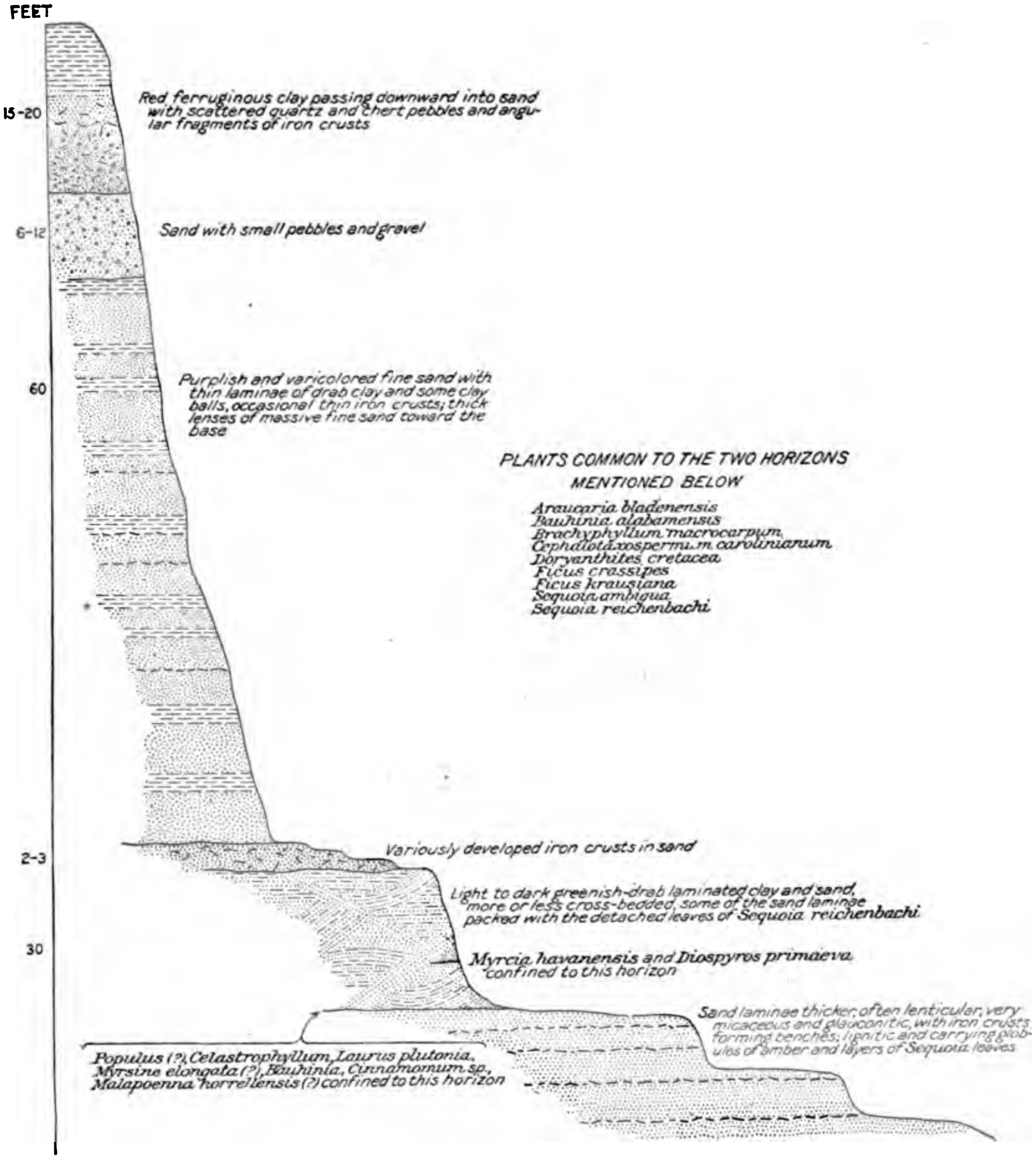
FEET
15-20
6-12
60
2-3
30
Red ferruginous clay passing downward into sand with scattered quartz and chert pebbles and angular fragments of iron crusts
Sand with small pebbles and gravel
Purplish and varicolored fine sand with thin laminae of drab clay and some clay balls, occasional thin iron crusts; thick lenses of massive fine sand toward the base
PLANTS COMMON TO THE TWO HORIZONS MENTIONED BELOW
Araucaria bladenensis
Bauhinia alabamensis
Brachyphyllum macrocarpum
Cephalotaxospermum carolinianum
Doryanthites cretacea
Ficus crassipes
Ficus krausiana
Sequoia ambigua
Sequoia reichenbachi
Variously developed iron crusts in sand
Light to dark greenish-drab laminated clay and sand, more or less cross-bedded, some of the sand laminae packed with the detached leaves of Sequoia reichenbachi
Myrcia havanensis and Diospyros primaeva confined to this horizon
Sand laminae thicker, often lenticular, very micaceous and glauconitic, with iron crusts forming benches; lignitic and carrying globules of amber and layers of Sequoia leaves
Populus (?), Celastrophyllum, Laurus plutonia, Myrsine elongata (?), Bauhinia, Cinnamomum sp., Malapoenna horrellensis (?) confined to this horizon

FIGURE 9.—Section of the Eutaw formation exposed in one of the deep gullies 2 miles southeast of Havana, Hale County, Ala.

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[1] Cockerell, T. D. A., U. S. Nat. Mus. Proc., vol. 51, pp. 98-99, fig. 6, 1916.

Dewalquea smithi Berry.
Diospyros primaeva Heer.
Ficus crassipes Heer.
    krausiana Heer.
    ovatifolia Berry.
Halymenites major Lesquereux.
Laurophyllum elegans Hollick.
Manihotites georgiana Berry.
Phragmites prattii Berry.
Phyllites asplenioides Berry.
Pterospermites carolinensis Berry.
Salix eutawensis Berry.

COMPOSITION AND ECOLOGIC CONDITIONS INDICATED BY THE EUTAW FLORA.

The Eutaw flora is far from representative of the flora that flourished during the deposition of the sediments of the Eutaw formation, as the majority of the plants that have been found came from the basal beds of the formation, in which the flora had not undergone any marked changes from that which lived in late Tuscaloosa time. It is, furthermore, not representative of the flora of early Eutaw time, because most of the plant remains had undergone much maceration, the consequent trituration having weeded out nearly all but the more coriaceous forms.

The known flora numbers but 43 species. No thallophytes (except the doubtful *Halymenites*) or bryophytes are represented; there is 1 fern, 9 gymnosperms, 2 monocotyledons, and 30 dicotyledons. The gymnosperms, although few in number, are of especial interest in the variety of forms represented. *Cephalotaxospermum* is represented by fruits very similar to those of the existing genus *Cephalotaxus*. *Brachyphyllum* is an older Mesozoic type without any close modern relatives. The *Sequoia* is the well-known and wide-ranging *Sequoia reichenbachi*, which appears to have been much more abundant in the Eutaw than in the Tuscaloosa. The *Tumion* is poorly represented. By far the most abundant type is *Araucaria bladenensis*, a form very abundant in the Black Creek formation and one scarcely distinguishable from the existing broad-leafed *Araucaria bidwilli*. Characteristic modern-appearing cone scales are represented by *Araucaria jeffreyi*. Perhaps the most remarkable type is the fernlike *Androvettia elegans*, a form without any nearly allied existing representatives.

The Monocotyledonae are of slight botanic interest. The *Phragmites* represents some Eutaw sedge or grass and the *Doryanthites* represents a large parallel-veined species of unknown affinity.

The 30 dicotyledons represent 11 orders of which the largest is the Thymeleales, with 5 species. There are 3 species each of Salicales, Urticales, Ranales, and Ericales; 2 each of Rosales, Rhamnales, and Myrtales; and 1 each of Juglandales, Geraniales, Umbellales, and Ebenales. Thus 23 belong to the Choripetalae and 4 to the Gamopetalae, the former being divided into 7 Apetalae and 16 Polypetalae. The order Sapindales, which had 15 species in the Tuscaloosa, the most important genus being *Celastrophyllum*, is entirely unrepresented.

The dicotyledonous families have 30 representatives, of which the largest is the Lauraceae with 5 species. The Salicaceae, Moraceae, and Ericaceae? have 3 species each; the Magnoliaceae, Caesalpiniaceae, Rhamnaceae, and Myrtaceae have 2 species each, and the Juglandaceae, Menispermaceae, Euphorbiaceae, Araliaceae, and Ebenaceae have 1 each. The most remarkable dicotyledon of the Eutaw is *Manihotites georgiana*, which had irregularly lobed subpeltate leaves 48 centimeters in diameter.

The Eutaw flora is far too small to serve for any conclusive deductions regarding ecologic or other physical conditions, and what has been said regarding this feature of the much more extensive Tuscaloosa flora applies equally well to the Eutaw. The basal Eutaw materials are evidently shallow-water sediments, but they do not show evidence of current bedding greater than that shown by the Tuscaloosa. It is in the clays that we see the differences both in lithology and in the contained flora. This clearly indicates one of two conditions. Either the Eutaw coast line lacked the estuaries with their bars, lagoons, or bayous of quiet waters and their mud flats which offer such exceptional opportunities for the preservation of plant foliage, or such deposits if formed have been subsequently destroyed by erosion. The Eutaw coast line was probably less broken than that of the Tuscaloosa, and doubtless some of the phytologic records of the Eutaw have been eroded; certainly vegetable matter was abundant in the Eutaw sea. This abundance is indicated by the lignitic character of many of the lower sands and by the dark carbonaceous clays. All that I have seen, however, was evidently subject to the action of the water a long time before entombment. The logs are thoroughly bored by some Eutaw representative of the modern Teredo. A calcified log 6 or 7 inches in diameter, found at Broken Arrow Bend, was thickly covered on one side with a fine set of nearly adult individuals of *Ostrea cretacea*, indicating the shallowness of the waters, because the spat of the Ostreidae do not set in deep water.

An effort to picture accurately the environment of this flora is beset with unusual difficulties, as may be imagined from what has already been said. It is safe to assume that the climate was mild and humid, the latter being probably the most important factor aside from the absence of frost. That the temperature was not tropical in character we may assume from the manner in which this flora preserves its integrity if traced northward over at least 10° of latitude. Judged by the facts of the present-day geographic distribution of plants, this flora presents an antipodean facies with its abundant Araucarieae, but this is only another way of emphasizing its Mesozoic character, as the abundant evidence at our command shows that these types were practically cosmopolitan in the Mesozoic. Another feature which seems strange to modern plant geographers is the curious mingling of forms, which in the existing flora are to a greater or less extent climatically segregated. Willows and walnuts growing with figs, laurels, and araucarias would indeed be anomalous in the present flora, but this and similar associations are familiar enough in fossil floras not only during the Mesozoic but well into the Cenozoic.

Even though no close comparisons with modern ecologic groups are possible, it would seem that the Eutaw flora, like that of the Tuscaloosa, if it were living at the present time, would be included by ecologic botanists under that somewhat elastic head which Schimper calls "temperate rain forests." In no other modern plant associations do we find that commingling of temperate and tropical types that we find in certain present-day temperate rain forests, as for example those of southern Chile, southern Japan, northern Australia, and New Zealand. In the last-mentioned country we find aralias, laurels, *Cinnamomum*, *Magnolia*, and *Sterculia* associated with *Quercus*, *Fagus*, *Gleichenia*, *Dryopteris*, *Dicksonia*, and other forms. In some respects this type in New Zealand is the most tropical in its facies and more like our eastern American Upper Cretaceous floras than any other existing flora. In New Zealand conifers are abundant and include forms with reduced leaves like *Libocedrus* and *Dacrydium*, as well as forms with broad leaves like *Dammara*, *Podocarpus*, and *Phyllocladus*. Dicotyledonae are numerous and varied, including between 100 and 150 species, among which forms of Myrtaceae, Lauraceae, Proteaceae, etc., with coriaceous leaves are prominent. The undergrowth is rich in tree ferns and various genera of Araliaceae.

When this modern flora is compared element for element with the eastern Gulf Cretaceous floras naturally many differences become apparent, but the resemblance between the two is remarkable. In the eastern Gulf Cretaceous floras *Sequoia*, *Brachyphyllum*, and *Widdringtonites* represent the narrow or scale-leaved conifers, *Dammara* and *Araucaria* the broad-leaved araucarias, and *Androvettia* and *Protophyllocladus* the modern *Phyllocladus*. The dicotyledons are numerous and varied, with a mixing of temperate and tropical types and with numerous coriaceous forms belonging to a number of the same families as do the New Zealand plants. Aralias are common in both the eastern Gulf Cretaceous and the modern floras. That the Cretaceous rainfall was plentiful may be inferred not only from the species of plants preserved but also from the formation of dripping points on various leaves, this feature being especially emphasized in the Tuscaloosa flora.

SELMA CHALK.

It is not within the province of this report to discuss the strictly marine and non plant-bearing deposits known as the Selma chalk. A brief statement is demanded, however, in order not to leave a hiatus in the discussion.

The Selma chalk is one of the most persistent lithologic units in the entire Coastal Plain and consists for the most part of massively bedded, usually lithified calcareous clay or argillaceous limestone.

The Selma chalk, long known as the "Rotten limestone," outcrops from east-central Alabama to the southern part of Benton County, in west Tennessee, forming the so-called Black Prairie country. In the area of its maximum development along Tombigbee River in west-central Alabama it outcrops as a broad belt and attains a thickness of at least 1,000 feet, extending to the extreme top of the Upper Cretaceous. It is a moderately shallow water deposit, as is shown by the abundance of fossil Ostreidae, and seems to owe its peculiar character to the absence of terrigenous materials. As I have previously stated, it is a lithologic and not a chronologic unit, the careful faunal studies of Stephenson having shown that it is partly the equivalent of the Eutaw and largely the equivalent of the Ripley. The various faunal lines have been traced successfully from the sands and clays of the Chattahoochee basin through the chalk to the sands and clays of northeastern Mississippi. The bearing of the Selma chalk on the Upper Cretaceous physiography has been mentioned in discussing the delta character of the Tuscaloosa deposits.

RIPLEY FORMATION.

HISTORICAL SKETCH.

The Ripley formation was named in 1860 by E. W. Hilgard[1] after the town of Ripley, in Tippah County, Miss., which is 3 miles southwest of the classic fossiliferous Ripley deposits exposed along Owl Creek.

The limits of the Ripley have been indefinite for more than half a century, any fossiliferous Upper Cretaceous sand being usually considered Ripley until the studies of Stephenson previously mentioned. The history of the study of these deposits need not concern us further, the literature containing absolutely no reference to fossil plants except a brief preliminary report on the Cretaceous flora of Georgia which I published in 1910.[2]

AREAL DISTRIBUTION.

The beds to which the name Ripley formation has been applied outcrop from Twiggs County, in central Georgia, to central Alabama where they are interrupted by the synchronous deposits of the upper part of the Selma chalk. The Selma chalk forms the top of the Upper Cretaceous for most of the distance between central Alabama and Houston County, Miss. From that point to the head of the Mississippi embayment the Ripley deposits are continuous. In Georgia the outcrop is from 10 to 15 miles wide, westward in Alabama to where it passes into the chalk phase it is from 25 to 30 miles, and beyond the chalk in northeastern Mississippi it lessens to about 12 miles at the Mississippi-Tennessee boundary. It has narrowed to about 6 miles at the Tennessee-Kentucky boundary, which width it maintains across Kentucky and southern Illinois.

LITHOLOGIC CHARACTER.

The Ripley materials are predominantly marine sands massively bedded, dark gray to greenish black in color, more or less calcareous, micaceous, pyritiferous, glauconitic, and argillaceous, according to the conditions of sedimentation in different parts of the Ripley sea. They are usually fossiliferous, sometimes enough so to constitute shell marls. Ledges of sandy limestone are developed locally. Some distance east of the Selma chalk, as in the Chattahoochee basin, the Ripley has been estimated to be about 1,000 feet thick, getting thinner eastward in Georgia, where it becomes more definitely a deposit of littoral sands. It also is thinner in the upper embayment, having a reported thickness of 400 feet at Wickliffe, Ky.; 54 feet at Cairo, Ill.; and 204 feet at Paducah, Ky.

STRATIGRAPHIC RELATIONS.

The Ripley formation rests without apparent unconformity on the somewhat similar sands of the upper part of the Eutaw in the Chattahoochee basin. Eastward in Georgia it lies unconformably on the Lower Cretaceous. Westward across most of Alabama and Mississippi it is developed above the chalk phase (Selma chalk) which underlies it as far as the southern part of Benton County, in west Tennessee. From this point to the head of the embayment it rests on the embayment floor of Paleozoic rocks. It is overlain throughout its extent by the unconformable deposits of the Eocene.

PLANT LOCALITIES.

Small collections of fossil plants have been made at seven or eight localities in the Ripley, and I have seen undeterminable fragments at numerous other outcrops. At the Big Cut on the Southern Railway 1½ miles west of Cypress, Tenn., a lens of carbonaceous clay at the base of the western end of the exposure is full of leaf fragments, and they are also present in the iron crust capping the clay. I failed to obtain anything identifiable at this outcrop, but there is a specimen of *Myrcia havanensis* Berry in the National Museum collections, and Wade collected 2 additional species from this locality. I have seen fragments of what may have been this species at the base of Chalk Bluff on Ohio River 2¼ miles above Caledonia Landing, Pulaski County, Ill. Extended search at this outcrop failed to yield any positively determinable material. Glenn made a small collection east of Benton, in Marshall County, Ky.[1] I have examined this collection and visited the outcrop without being able to determine any of the plant fragments.

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[1] Hilgard, E. W., Report on the geology and agriculture of Mississippi, pp. 62, 83-95, 1860.

[2] Berry, E. W., Contributions to the Mesozoic flora of the Atlantic Coastal Plain; VI, Georgia: Torrey Bot. Club Bull., vol. 37, pp. 503-511, 1910.

In the northwestern part of Benton County, Tenn., L. W. Stephenson collected a few fossil plants from exposures along the Camden-Paris public road. (See Pl. IV, *A*.) I have been able to recognize *Myrcia havanensis* Berry, *Myrica ripleyensis* Berry, and *Sabalites* sp.

Just above the mouth of Cowikee Creek, in Barbour County, Ala., there is an exposure of 30 to 40 feet of massive, compact glauconitic, argillaceous, micaceous sand carrying plant fragments associated with invertebrates of the genera *Nucula*, *Ostrea*, *Cymella*, *Liopistha*, and *Leptosolen*.[2] The plants are fragmentary and bear evidence of having been in the water a long time before fossilization. The following forms have been recognized:

Bauhinia ripleyensis Berry.
Fern, undeterminable.
Laurus? sp.
Platanus sp.
Salix? sp.
Sapindus? sp.

I have been unable to identify any of these with previously known forms and they are so inconclusive that only the *Bauhinia* and the *Platanus* are included in the systematic descriptions that follow.

There are two localities in Georgia from which Ripley plants have been collected, one 6 miles east of Buena Vista on the Buena Vista-Tazewell Road, in Marion County, where the following section is exposed:[3]

Section on the Buena Vista-Tazewell Road, Marion County, Ga.

	Feet.
Ripley formation:	
Marine member (brownish weathered sands).....	70
Cusseta sand member (coarse light-colored cross-bedded arkosic sand locally with iron concretions and both light and dark clay lenses; from a lens of black clay near the base fossil plants were collected)........................	50

The following 6 species, collected by Stephenson, have been determined from this outcrop:

Andromeda novaecaesareae Hollick.
Araucaria bladenensis Berry.
Doryanthites cretacea Berry.
Eucalyptus angusta Velenovsky.
Ficus georgiana Berry.
Manihotites georgiana Berry.

The most abundant form is the curious monocotyledon *Doryanthites cretacea*.

The second Ripley plant locality in Georgia is in a cut along the Central of Georgia Railway 1½ miles northeast of Byron, in Houston County. The materials as described by Stephenson[4] are light cross-bedded sands of the Cusseta sand member underlain by drab clays with sand lenses, and a layer of dark carbonaceous clay 6 feet thick in the lower part of the section yielded the following plants: *Araucaria jeffreyi* Berry, *Cunninghamites elegans* (Corda) Endlicher, and *Dryopterites stephensoni* Berry.

The most extensive known collection of plants from the Ripley formation is that which was made by Bruce Wade from a small clay lens near the base of the McNairy sand member of the Ripley formation 2½ miles southwest of Selmer, in McNairy County, Tenn. Because of the exceptionally extensive fauna preserved in the Upper Cretaceous deposits of this region I have introduced a diagrammatic section (fig. 10) showing the lithology and the relative geologic and geographic relations of the plant localities at Selmer and Big Cut to those which have furnished the marine faunas of Coon Creek, Sand Hill, and Trims Mill.

The following species of plants have been identified from the McNairy sand member of the Ripley formation from the locality near Selmer:

Bauhinia ripleyensis Berry.
Cinnamomum sp.

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[1] Glenn, L. C., Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in Illinois: U. S. Geol. Survey Water-Supply Paper 164, p. 27, 1906.

[2] Stephenson, L. W., Georgia Geol. Survey Bull. 26, pp. 172, 173, 1911.

[3] Idem, p. 163.

[4] Idem, pp. 170-171.

Cissites crispus Velenovsky.
Dryophyllum gracile Debey.
Eugenia? anceps Berry.
Magnolia capellini Heer.
Malapoenna horrellensis Berry.
Manihotites georgiana Berry.
Myrcia havanensis Berry.
Myrica ripleyensis Berry.
Sabalites sp.
Sterculia snowii tennesseensis Berry.

The fossil plants of the Ripley are so few in number and in the main so poorly preserved that any discussion of the general character of the Ripley flora or of the ecologic conditions which it indicates is out of the question.

Grewiopsis formosa.
    tuscaloosensis.
Hymenaea fayettensis.
Jungermannites cretaceus.
Leguminosites ingaefolia.
    shirleyensis.
    tuscaloosensis.
Lycopodites tuscaloosensis.
Malapoenna cottondalensis.
Menispermites integrifolius.
    trilobatus.
Myrica dakotensis minima.
Oreodaphne shirleyensis.
Persoonia lesquereuxii minor.
Phyllites shirleyensis.
    pistiaeformis.

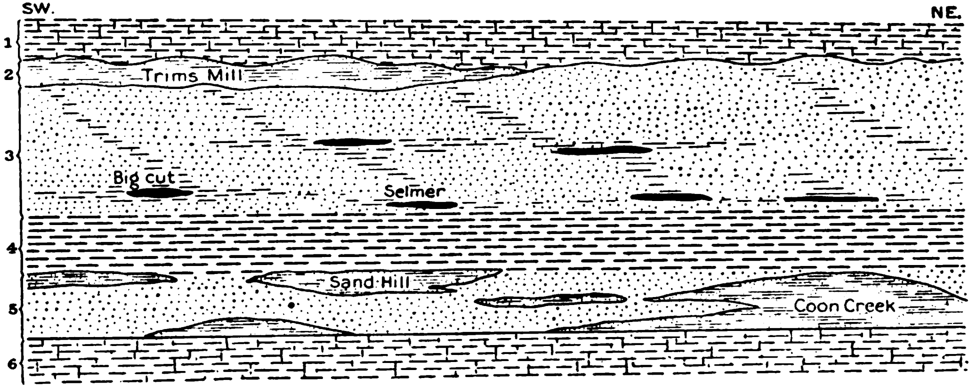

FIGURE 10.—Diagrammatic section of the Ripley formation in McNairy County, Tenn., from northeast to southwest. No. 1 is chalky clay of Midway age. Nos. 2 to 5, inclusive, belong to the Ripley formation. No. 2, consisting of sandy fossiliferous marl, is the northeastern extension of the Owl Creek beds of Lowe; No. 3 is the McNairy sand member; No. 4, ferruginous clay; and No. 5, sand with fossiliferous marl lenses and *Halymenites*-bearing sands, being the fossiliferous horizon of Coon Creek. No. 6 (chalky clay) is the Selma chalk. Localities named indicate positions of faunas and floras.

BEARING OF THE FLORAS ON CORRELATION.

CORRELATION OF THE TUSCALOOSA FLORA.

The following 47 Tuscaloosa species are new and have no known outside distribution:

Aralia cottondalensis.
Calycites sexpartitus.
Capparites cynophylloides.
    orbiculatus.
Carpolithes tuscaloosensis.
Cassia vaughani.
Celastrophyllum alabamensis.
    crenatum ellipticum.
    gymindaefolium.
    precrassipes.
    shirleyensis.
Cladophlebis alabamensis.
Cocculus polycarpaefolius.
    problematicus.
Conocarpites formosus.
Eorhamnidium cretaceum.
Equisetum? sp.
Eugenia tuscaloosensis.
Ficus alabamensis.
    fontainii.
    shirleyensis.
Piperites tuscaloosensis.
Platanus asperaeformis.
    shirleyensis.
Populites tuscaloosensis.
Proteoides conospermaefolia.
Sapindus variabilis.
Sapotacites ettingshauseni
    formosus.
    shirleyensis.
Sphaerites alabamensis.

These species are obviously of slight value in exact correlation, nevertheless, with the exception of the new genera *Capparites*, *Conocarpites*, *Eorhamnidium*, and *Piperites* and the two genera *Grewiopsis* and *Platanus*, all the genera are characteristic of the flora of the Dakota sandstone of the Rocky Mountain region, the Raritan and Magothy formations of the northern Coastal Plain, and the Cenomanian of Europe. Two of the varieties are varieties of well-known Dakota forms. The variation shown by *Celastrophyllum* finds its parallel in the Dakota and Raritan and nowhere else. This genus has 12 species in the

Tuscaloosa, nearly as many in the Dakota and Raritan, and some in the Magothy of New Jersey, and the Black Creek formation of the Carolinas, but not a single species in the Eutaw formation, in the abundant flora of the Montana group, or in the extensive Senonian floras of Europe. The genus is moreover abundant in the Patapsco formations, at the top of the Lower Cretaceous, and is of the greatest importance in fixing the age of the Tuscaloosa. The new species of *Hymenaea* is related to a Dakota sandstone form, as is the *Aralia*, and *Cladophlebis* is distinctly a survivor from the Lower Cretaceous.

The following 6 Tuscaloosa plants have been recorded from the Lower Cretaceous:

Abietites foliosus.
Asplenium dicksonianum.
Celastrophyllum brittonianum.
Gleichenia delicatula.
Sequoia ambigua.
    reichenbachi.

The only one of these that is a characteristic Lower Cretaceous species is *Abietites foliosus*, and it is probably allied to the structural material referred to *Prepinus* from the Raritan formation of the Upper Cretaceous. *Asplenium dicksonianum* occurs in both the Raritan and the Dakota, the *Celastrophyllum* in the Raritan of New Jersey and the Patoot beds of Greenland, *Sequoia ambigua* in the Magothy, and *Sequoia reichenbachi* through the entire Cretaceous. Without further discussion the suggestion that any part of the Tuscaloosa formation is of Lower Cretaceous age is dismissed as an impossibility.

The relation of the Tuscaloosa flora to other Upper Cretaceous floras may next be considered. Sixteen Tuscaloosa species are found in the basal beds of the Eutaw formation in Alabama and Georgia and others are represented by closely allied forms, showing that the Tuscaloosa flora and that of the basal Eutaw are very closely related. The total number of plants known from the Eutaw is 41, of which 50 per cent are survivors from the Tuscaloosa. With the still younger Ripley flora the resemblance is slight. Only 20 identifiable forms have been found in the Ripley and of these only *Andromeda novaecaesareae* and *Dryopterites stephensoni* occur in the Tuscaloosa.

A considerable flora has been recorded from the Black Creek formation in North and South Carolina. Twenty-eight Tuscaloosa forms are found in the typical Black Creek and 9 additional in the Middendorf arkose member of South Carolina, which is a basal lithologic phase of the Black Creek. The Black Creek is several hundred feet thick and carries a considerable marine fauna in its upper beds, which fauna, according to the studies of Stephenson, shows affinities with the Eutaw and basal Ripley faunas. Though a majority of the species common to the Tuscaloosa and the Black Creek (including the Middendorf member) formations are found in the lower beds of the Black Creek either at Court House Bluff, on Cape Fear River, or in the Middendorf member of South Carolina, the Black Creek flora is essentially a unit, the species diagnostic of the Eutaw in Alabama being common to the upper and lower parts of the Black Creek.

The relation of the Tuscaloosa flora to that of the northern Coastal Plain from Marthas Vineyard to Maryland as developed in the floras of the Raritan and Magothy formations is exceedingly close. There are 63 species common to the Tuscaloosa and Raritan and 62 common to the Tuscaloosa and Magothy. Of the 63 species common to the Raritan 14 are from the upper part of the Raritan and several additional are from unknown localities. A marked difference exists between the flora of the upper and lower parts of the Raritan, as I have shown in a recent publication devoted to the Raritan flora.[1] Fifty per cent of the upper Raritan flora does not occur in the more abundant lower Raritan flora, and the upper Raritan flora is closely allied to that of the overlying Magothy. For these reasons I consider that the lower Raritan is older than any part of the Tuscaloosa and that the basal part of the Tuscaloosa is the equivalent of the upper part of the Raritan.

The relation of the Tuscaloosa flora to that of the Magothy is very close, more than 41 per cent of the Tuscaloosa species being found in the Magothy. Obviously the two are nearly synchronous, although their lower limits do not correspond, because the upper part of the Raritan is considered to correspond with the lower part of the Tuscaloosa. Their upper limits are also probably not identical, as the Magothy formation is much thinner than the Tuscaloosa. The uppermost Tuscaloosa may correspond to more or less of the Matawan, because the few fossil plants found in the Matawan, comprising only 2 or 3 species, all are Magothy survivors. However, I am disposed to think that this resemblance is not important, as a considerable element of the Tuscaloosa flora survives in the Eutaw and as the invertebrates of the Eutaw are mainly Magothy and Matawan types, so that probably the Matawan is mainly to be correlated with the Eutaw, and possibly with the lower part of the Ripley as developed in the Chattahoochee region.

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[1] Berry, E. W., New Jersey Geol. Survey Bull. 3, 1911.

On turning to the western Gulf area we find in the scanty flora of the Woodbine sand of southern Texas 19 Tuscaloosa species, clearly indicating the substantial synchroneity of these two formations on opposite sides of the Mississippi embayment. Recently a small flora of 28 species has been collected by H. D. Miser from the Bingen formation in Pike and Howard counties, Ark.[1] Of these species 18 are common to the Tuscaloosa formation. Mr. Miser proposes to separate the Bingen formation into a lower and an upper member, and it is significant that the flora of the lower member is more closely related to that of the Tuscaloosa formation, whereas the flora of the upper member is more like that found in the Eutaw formation of the eastern Gulf area.

The floras of the Western Interior or Rocky Mountain province show the initial deposits of the Upper Cretaceous cycle of sedimentation, the Dakota sandstone, to be rich in fossil vegetation. Forty-eight Tuscaloosa plants are recorded from the Dakota and in addition nearly all the genera are common to the two areas with closely related species in both. To what extent the Dakota flora survived in Colorado time is unknown, so that comparisons between the East and the West lack precision. There are only four Tuscaloosa species recorded from the Montana group, one the widespread *Sequoia reichenbachi*, which because of its wide range is lacking in significance; another is *Sequoia heterophylla*, which ranges from the Cenomanian to the Emscherian in Europe; a third is *Geinitzia formosa*, whose later occurrence in both the Montana and the Senonian of Europe is to be regarded as an instance of survival; and the fourth *Gleichenia delicatula*, a survivor from the Lower Cretaceous that is said to occur in a disputed area in Wyoming, in rocks which may be Colorado instead of Montana in age. Moreover a large number of the genera represented in the flora of the Montana group are unrepresented in the Tuscaloosa, Raritan, or Magothy of the East. In consequence the facies is very different, and I have no hesitation in considering these eastern floras older than the known flora of the Montana group, an opinion which has been consistently held by all paleobotanic students who have examined the question.

To consider briefly the European Upper Cretaceous floras it is remarkable that 18 identical species should be found in the European Cenomanian, 2 in the florally poor Turonian, and 4 in the Senonian, 1 being the ubiquitous *Sequoia reichenbachi*, which is without significance, and none of the other three being angiosperms; two are conifers with an identical range in this country and the third is an *Asplenium* which survived from the Lower Cretaceous. Hence the evidence of the floras is overwhelmingly in favor of the pre-Senonian and pre-Montana age of the Tuscaloosa and allied floras. Thirty Tuscaloosa species are found in the Atane beds of Greenland and ten in the Patoot beds of Greenland, a distribution significantly in accord with the preceding statements.

The details of the range of the different elements of the Tuscaloosa flora both within the formation and elsewhere are shown in the tables of distribution which accompany this chapter.

CORRELATION OF THE EUTAW FLORA.

Four of the five localities are in the lower part of the Eutaw formation, which, in the Chattahoochee section, is estimated to be 400 or 450 feet thick, and the flora, which numbers 41 species, may be discussed as a unit.

The following species are new to science and are known only from these deposits. They are therefore of but slight value for purposes of precise correlation.

Androvettia elegans Berry.
Bauhinia alabamensis Berry.
Cupressinoxylon sp.
Menispermites variabilis Berry.
Paliurus upatoiensis Berry.
Zizyphus laurifolius Berry.

The *Androvettia* is closely related to a similar species found in the upper part of the Tuscaloosa formation in Mississippi and in the Black

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[1] Berry, E. W., Torrey Bot. Club Bull., vol. 43, pp. 167-190, pl. 7, 1917.

Creek formation in North Carolina. The other new species are without special significance except that they are referred to genera found in the Dakota and Magothy formations, and only the genus *Bauhinia* is found in the younger Ripley formation of the eastern Gulf area, and none, so far as I know, are represented in the flora of the Montana group of the Rocky Mountain province.

Of the Eutaw species 20 are survivors from the Tuscaloosa and 9 continue into the overlying Ripley; 8 of these make their appearance in the Eutaw and serve to give it a distinct floral facies. These 8 species are *Malapoenna horrellensis*, *Eucalyptus angusta*, *Halymenites major*, *Manihotites georgiana*, *Araucaria bladenensis*, *Araucaria jeffreyi*, *Doryanthites cretacea*, and *Myrcia havanensis*. All of these except the *Myrcia* and *Halymenites* are common to the Black Creek formation, and two of them, *Araucaria bladenensis* and *Doryanthites cretacea*, are found in the Magothy formation.

The Eutaw has 4 species common to the Woodbine sand of Texas, 6 to the Bingen formation of Arkansas, 15 to the Dakota sandstone of the West, 12 to the Raritan formation of the northern Coastal Plain, 15 to the Magothy formation of the northern Coastal Plain, 20 to the Black Creek formation of the Carolinas and 2 additional in its Middendorf member, 9 in the Atane beds of Greenland, 3 in the Patoot beds of Greenland, and 6 in the Cenomanian of Europe. One species, *Sequoia reichenbachi*, is common to the Montana group of the West and to the European Turonian and Senonian, and this is a species, as I have previously pointed out, that is without significance because of its wide geologic range. The parallelism between the Eutaw formation, the Black Creek formation of the Carolinas, and the Magothy formation of the northern Coastal Plain is even closer than the mere percentages would indicate, as it is based upon peculiar forms, such as the two species of *Araucaria*, the *Cephalotaxospermum*, and the *Doryanthites*, and not upon wide-ranging species. I consider that the basal plant-bearing portion of the Eutaw formation is synchronous with a large part of the Black Creek formation and with all of the Magothy formation. Because of the thinness of the Magothy it is probable that at least the basal part of the Matawan formation, which overlies the Magothy in the northern Coastal Plain, is also to be correlated with the Eutaw formation, as I understand the invertebrate faunas also indicate.

Comparisons between the Eutaw flora and that of the Upper Cretaceous of Texas, Kansas, and the Rocky Mountain province are more vague. The Eutaw is obviously younger than the Woodbine, as the comparison of the Woodbine with the Tuscaloosa has clearly indicated. (See p. 41.) The Eutaw undoubtedly represents a part of the Dakota flora, but beyond this statement the evidence is not specific enough. One fact stands out very clearly—the Eutaw flora has nothing in common with and is decidedly older than the Montana floras of the Rocky Mountain province, the stratigraphic succession necessitating a suggested synchronism with part of the Dakota sandstone and part of the Colorado group of the West.

The Eutaw flora also has nothing in common with the abundant Senonian floras of Europe, and whatever may be the conclusions drawn from a study of the invertebrate faunas of the overlying beds of the Eutaw, I have no hesitation in affirming that the flora found in its basal beds is pre-Senonian in age.

CORRELATION OF THE RIPLEY FLORA.

The flora found in the Ripley formation is so scanty, including only 21 identifiable species, of which 8 are new and confined to these beds, that accurate correlation is impossible.

The following 8 species, *Araucaria bladenensis*, *Araucaria jeffreyi*, *Halymenites major*, *Malapoenna horrellensis*, *Eucalyptus angusta*, *Doryanthites cretacea*, *Myrcia havanensis*, and *Manihotites georgiana*, are survivors from the Eutaw, and all of these but the *Myrcia*, *Halymenites*, and *Eucalyptus* are common to the Black Creek formation of the Carolinas, and two of them *Araucaria bladenensis* and *Doryanthites cretacea*, occur in the Magothy formation of the northern Coastal Plain.

The following species come from the lower beds of the Ripley formation:

Andromeda novaecaesareae Hollick.
Araucaria bladenensis Berry.
Araucaria jeffreyi Berry.
Cunninghamites elegans (Corda) Endlicher.
Doryanthites cretacea Berry.
Dryopterites stephensoni Berry.
Eucalyptus angusta Velenovsky.
Ficus georgiana Berry.
Manihotites georgiana Berry.

This list is of considerable significance, because all but the new species of *Dryopterites* and *Ficus* occur in the Black Creek formation, the first, second, and fourth are common to the Magothy formation, the first and sixth occur in the Tuscaloosa formation, and the first and seventh go back as far as the uppermost part of the Raritan.

The flora of the upper beds of the Ripley formation, though it consists of only *Dryophyllum gracile, Cissites crispus, Sterculia snowii tennesseensis, Cinnamomum* sp., *Malapoenna horrellensis, Eugenia? anceps, Halymenites major, Manihotites georgiana, Bauhinia ripleyensis, Myrcia havanensis, Myrica ripleyensis, Platanus* sp., and *Sabalites* sp., has little in common with the flora of the lower Ripley, and only three of these species afford a point of contact with older floras, the *Manihotites, Myrcia*, and *Malapoenna* making their appearance in the Eutaw.

Still another element of contrast is furnished by the presence in the upper Ripley of Cowikee Creek of the representatives of four other species, not specifically determinable but apparently unlike any of the older floras with which I am familiar. These were designated as *Fern* (undeterminable), *Laurus?* sp., *Salix?* sp., and *Sapindus?* sp.

It seems evident, in spite of the meager paleobotanic data, that the striking change in our eastern Upper Cretaceous floras, if there really was a striking change, which may well be questioned, took place after the deposition of the Cusseta sand member of the Ripley formation. It might perhaps be clearer to say that in the flora of the Ripley deposits above the Cusseta sand member all close similarities with earlier Cretaceous floras had been eliminated. One of the Ripley species, *Cunninghamites elegans*, and the dubious *Halymenites major*, are present in the flora of the Montana group of the West.

DISTRIBUTION OF THE TUSCALOOSA, EUTAW, AND RIPLEY FLORAS.

Details of distribution both within and outside the eastern Gulf area for all the units of the Tuscaloosa, Eutaw, and Ripley floras are assembled in the appended table.

Distribution of species contained in the Tuscaloosa, Eutaw, and Ripley floras.

	Tuscaloosa formation.															Eutaw formation.					Ripley formation.						Woodbine sand, Tex.	Dakota sandstone, Western Interior.	Raritan formation, northern Coastal Plain.	Magothy formation, northern Coastal Plain.	Typical deposits of Black Creek formation, North Carolina and South Carolina.	Middendorf arkose member of Black Creek formation, South Carolina.	Atane beds, Greenland.	Patoot beds, Greenland.	Montana group, Western Interior.	Cenomanian, Europe.	Turonian, Europe.	Senonian, Europe.	Lower Cretaceous.	Bingen formation of Arkansas.
	Near Iuka, Miss.	Glen Allen, Ala.	Shirleys Mill, Ala.	Tuscaloosa, Ala.	Cottondale, Ala.	Southwest of Northport, Ala.	Upper ravine, Snow place, Ala.	Big gully, Snow place, Ala.	Robertsons Landing, Ala.	Sanders Ferry Bluff, Ala.	Whites Bluff, Ala.	Soap Hill, Ala.	Near Maplesville, Ala.	Jones Ferry, Ala.	Near Centerville, Ala.	Near Havana, Ala.	McBrides Ford, Ga.	Chimney Bluff, Ga.	Broken Arrow Bend, Ga.	Coffee Bluff, Tenn.	Near Selmer, Tenn.	Near Camden, Tenn.	Cowikee Creek, Ala.	Near Buena Vista, Ga.	Near Byron, Ga.	Cypress, Tenn.														
Abietites foliosus (Fontaine) Berry							×	×																															×	
Acerates amboyensis Berry			×							×																			×		×									
Andromeda cretacea Lesquereux?																	×											×												
grandifolia Berry		×	×	×			×																						×	×	×									
novaecaesareae Hollick		×	×					×												×				×			×		×	×	×	×								×
parlatorii Heer		×	×	×	×		×	×								×												×	×	×	×		×							×
wardiana Lesquereux	×		×														×			×								×												
Androvettia carolinensis Berry	×																														×									
elegans Berry																	×																							
Aralia cottondalensis Berry					×																																			
eutawensis Berry																	×														×									
Araucaria bladenensis Berry																×		×						×						×	×									
jeffreyi Berry																		×							×						×									
Asplenium dicksonianum Heer			×																									×	×				×			×		×	×	
Bauhinia alabamensis Berry																×																								
cretacea Newberry			×		×											×													×											
marylandica Berry		×	×		×																									×										
ripleyensis Berry																					×		×																	
Brachyphyllum macrocarpum formosum Berry			×								×					×	×										×			×	?					?		?		
Calycites sexpartitus Berry								×																																
Capparites cynophylloides Berry			×																																					
orbiculatus Berry			×																																					
Carpolithus floribundus Newberry			×																										×	×										
tuscaloosensis Berry						×		×						×																										
Cassia vaughani Berry		×																																						
Celastrophyllum alabamensis Berry															×																									
brittonianum Hollick			×																										×										×	
carolinensis Berry							×	×																								×								
crenatum Heer					×			×																					×		×	×	×	×						
crenatum ellipticum Berry			×																																					

Celastrophyllum decurrens Lesquereux			×																									×	×											
grandifolium Newberry			×		×																								×	?										
gymindaefolium Berry			×																																					
newberryanum Hollick			×																										×	×			?							
precrassipes Berry			×																																					
shirleyensis Berry			×																																					
undulatum Newberry					×																								×		×									
Cephalotaxospermum carolinianum Berry																×															×									
Cinnamomum heerii Lesquereux?																	×			×							×	×		×	×									
newberryi Berry		×	×		×												×											×	×	×	×	×	×	×						?
sp.																					×																			
Cissites crispus Velenovsky																					×																	×		
formosus Heer		×																										×	×				×							
Citrophyllum aligerum (Lesquereux) Berry			×		×																							×	×	×	×	×								
Cladophlebis alabamensis Berry								×																																
Cocculus cinnamomeus Velenovsky?					×																									×						×				
polycarpaefolius Berry					×																																			
problematicus Berry		×																																						
Colutea obovata Berry			×																											×										
Conocarpites formosus Berry		×																																						
Cordia apiculata (Hollick) Berry		×	×		×																								×	×										×
Cornophyllum obtusatum Berry					×																										×									
vetustum Newberry		×																									×		×											
Crotonophyllum panduraeformis Berry			×																													×								
Cunninghamites elegans (Corda) Endlicher																									×				?	×	×	?		×	×	×	×	×		
Cupressinoxylon sp.																				×																				
Cycadinocarpus circularis Newberry		×																											×	×	×									
Cyperacites sp. Hollick						×																								×										
Dammara borealis Heer			×				×	×																					×	×	×		×			×				
Dermatophyllites acutus Heer			×																														×							
Dewalquea smithi Berry			×								×									×												×								
Dicksonia groenlandica Heer			×				×	×																					×				×	×						×
Diospyros amboyensis Berry			×																										×											
primaeva Heer		×	×	×	×											×				×							×	×	×	×	×	×	×	×						
rotundifolia Lesquereux		×	×																									×		×										
Doryanthites cretacea Berry																×								×						×	×									
Dryophyllum gracile Debey																					×					×												×		
Dryopterites stephensoni Berry								×																	×															
Eorhamnidium cretaceum Berry			×		×																																			
platyphylloides (Lesquereux) Berry					×																							×												
Equisetum? sp. Berry								×																																
Eucalyptus angusta Velenovsky																	×							×					×			×				×			×	
geinitzi (Heer) Heer						×	×	×					×														×	×	×	×	×	×	×			×				
latifolia Hollick							×																							×										
Eugenia anceps Berry																					×																			
tuscaloosensis Berry			×		×																																			
Ficus alabamensis Berry			×																																					
crassipes (Heer) Heer							×	×		×								×		×								×		×			×							×
daphnogenoides (Heer) Berry		×	×	×	×		×	×																			×	×	×	×	×	×								×
fontainii Berry			×		×																																			
georgiana Berry																								×																
inaequalis Lesquereux			×		×																							×			×									
krausiana Heer		×	×		×		×			×						×		×		×								×		×						×				

Distribution of species contained in the Tuscaloosa, Eutaw, and Ripley floras—Continued.

	Tuscaloosa formation.															Eutaw formation.					Ripley formation.																			
	Near Iuka, Miss.	Glen Allen, Ala.	Shirleys Mill, Ala.	Tuscaloosa, Ala.	Cottondale, Ala.	Southwest of Northport, Ala.	Upper ravine, Snow place, Ala.	Big gully, Snow place, Ala.	Robertsons Landing, Ala.	Sanders Ferry Bluff, Ala.	Whites Bluff, Ala.	Soap Hill, Ala.	Near Maplesville, Ala.	Jones Ferry, Ala.	Near Centerville, Ala.	Near Havana, Ala.	McBrides Ford, Ga.	Chimney Bluff, Ga.	Broken Arrow Bend, Ga.	Coffee Bluff, Tenn.	Near Selmer, Tenn.	Near Camden, Tenn.	Cowikee Creek, Ala.	Near Buena Vista, Ga.	Near Byron, Ga.	Cypress, Tenn.	Woodbine sand, Tex.	Dakota sandstone, Western Interior.	Raritan formation, northern Coastal Plain.	Magothy formation, northern Coastal Plain.	Typical deposits of Black Creek formation, North Carolina and South Carolina.	Middendorf arkose member of Black Creek formation, South Carolina.	Atane beds, Greenland.	Patoot beds, Greenland.	Montana group, Western Interior.	Cenomanian, Europe.	Turonian, Europe.	Senonian, Europe.	Lower Cretaceous.	Bingen formation of Arkansas.
Ficus ovatifolia Berry																	X			X									X	X	X									?
shirleyensis Berry			X																																					
woolsoni Newberry		X	X	X	X																								X	X										
Geinitzia formosa Heer			X		X																								X	X					X			X		
Gleichenia delicatula Heer			X																										X						X	X			X	
Grewiopsis formosa Berry			X																																					
tuscaloosensis Berry			X																																					
Halymenites mayor Lesquereux																				X	X																			
Hymenaea fayettensis Berry			X																																					
Ilex masoni Lesquereux		X			X																							X												
Inga cretacea Lesquereux			X																								X	X												
Juglans arctica Heer			X		X												X											X	X	X	X	X	X							
Jungermannites cretaceus Berry			X																																					
Kalmia brittoniana Hollick			X																										X		X									
Laurophyllum angustifolium Newberry?							X																						X	X										
elegans Hollick																				X																				
nervillosum Hollick			X																										X											
Laurus plutonia Heer			X		X											X											X	X	X	X		X	X	X		X				
Leguminosites ingaefolia Berry		X	X																																					
omphalobioides Lesquereux			X																									X	X	X										X
shirleyensis Berry			X																																					
tuscaloosensis Berry			X																																					
Liriodendron meekii Heer					X																							X	X	?	?		X			X				X
Liriodendropsis angustifolia Newberry			X																										X	X										
constricta Ward			X																										?	X										
simplex Newberry		X	X																										X	X										
Lycopodites tuscaloosensis Berry		X	X																																					
Lycopodium cretaceum Berry		X	X																													X								

Magnolia boulayana Lesquereux			×														×										×	×	×	×										
capellinii Heer					×												×				×							×	?	×	×		×			×				
hollicki Berry			×																										×	×										
lacoeana Lesquereux		×	×																									×	×	×										
longipes Newberry			×		×																								×	×										
newberryi Berry		×																											×	×	×									
obtusata Heer			×																									×		×			×							
speciosa Heer		×	×	×	×																						×	×	×	×						×				
Malapoenna cottondalensis Berry					×																																			
cretacea (Lesquereux) Knowlton					×																							×												
falcifolia (Lesquereux) Knowlton			×																								×	×		×										
horrellensis Berry																×			×		×	×				×					×									
Manihotites georgiana Berry																	×			×	×			×							×									×
Marattia cretacea Velenovsky?		×																																		×				
Menispermites integrifolius Berry					×																																			×
trilobatus Berry			×																																					
variabilis Berry																	×																							
Myrcia havanensis Berry																×					×	×				×														
Myrica dakotensis minima Berry		×																																						
emarginata Heer			×		×																						×	×	×				×							
longa (Heer) Heer							×	×																			×	×		×			×	×						×
ripleyensis Berry																					×	×																		
Myrsine borealis Heer		×	×					×																				×	×	×	×		×							
gaudini (Lesquereux) Berry		×			×	×																						×	×	×	×									
Nyssa snowiana Lesquereux			×																									×												
Oreodaphne alabamensis Berry					×																						×													
shirleyensis Berry			×																																					
Palaeocassia laurinea Lesquereux			×																								×	×												
Paliurus upatoiensis Berry																	×																							
Panax cretacea Heer			×																											×			×							
Persea valida Hollick					×																									×										
Persoonia lesquereuxii Knowlton			×																									×	×	×										
lesquereuxii minor Berry		×	×																																					
Phaseolites formus Lesquereux			×		×																							×			×					×				
Phragmites pratti Berry																			×	×											×									
Phyllites asplenioides Berry																				×																				
pistiaeformis Berry	×	×																																						
shirleyensis Berry			×																																					
Pinus raritanensis Berry					×																								×	×		×								
Piperites tuscaloosensis Berry			×	×																																				
Platanus asperaeformis Berry			×																																					
latior (Lesquereux) Knowlton					×																							×												
shirleyensis Berry			×		×																																			
sp. Berry																							×																	
Podozamites marginatus Heer								×				×																	×	×			×			?				×
Populites tuscaloosensis Berry		×		×																																				
Populus hyperborea Heer					×																							×					×							
Proteoides conospermaefolia Berry			×																																					
Protodammara speciosa Hollick and Jeffrey			×																										×											
Protophyllocladus subintegrifolius (Lesquereux) Berry					×																							×	×	×			×							
Pterospermites carolinensis Berry		×	×		×															×											×									
Rhamnus tenax Lesquereux			×																								×	×												
Sabalites sp. Berry																					×	×																		

Distribution of species contained in the Tuscaloosa, Eutaw, and Ripley floras—Continued.

	Tuscaloosa formation.															Eutaw formation.					Ripley formation.						Woodbine sand, Tex.	Dakota sandstone, Western Interior.	Raritan formation, northern Coastal Plain.	Magothy formation, northern Coastal Plain.	Typical deposits of Black Creek formation, North Carolina and South Carolina.	Middendorf arkose member of Black Creek formation, South Carolina.	Atane beds, Greenland.	Patoot beds, Greenland.	Montana group, Western Interior.	Cenomanian, Europe.	Turonian, Europe.	Senonian, Europe.	Lower Cretaceous.	Bingen formation of Arkansas.
	Near Iuka, Miss.	Glen Allen, Ala.	Shirleys Mill, Ala.	Tuscaloosa, Ala.	Cottondale, Ala.	Southwest of Northport, Ala.	Upper ravine, Snow place, Ala.	Big gully, Snow place, Ala.	Robertsons Landing, Ala.	Sanders Ferry Bluff, Ala.	Whites Bluff, Ala.	Soap Hill, Ala.	Near Maplesville, Ala.	Jones Ferry, Ala.	Near Centerville, Ala.	Near Havana, Ala.	McBrides Ford, Ga.	Chimney Bluff, Ga.	Broken Arrow Bend, Ga.	Coffee Bluff, Tenn.	Near Selmer, Tenn.	Near Camden, Tenn.	Cowikee Creek, Ala.	Near Buena Vista, Ga.	Near Byron, Ga.	Cypress, Tenn.														
Salix eutawensis Berry																			X												X									
flexuosa Newberry			X	X			X	X	X	X	X		X				X	X	X									X	X	X	?	X								X
lesquereuxii Berry		X	X	X	X			X		X								X										X	X	X	X	X								X
meekii Newberry			X																									X	X	X										
Sapindus morrisonii Heer						X																					X	X	?	X		X	X	X						X
variabilis Berry		X	X																																					
Sapotacites ettingshauseni Berry			X																																					
formosus Berry			X																																					
shirleyensis Berry			X																																					
Sassafras acutilobum Lesquereux					X																							X	X	X						X				
Sequoia ambigua Heer							X	X								X														X			X						X	
fastigiata (Sternberg) Heer								X																				X					X	X		X				
heterophylla Velenovsky			X								X																		X	X	X				X	X	X	X		X
reichenbachi (Geinitz) Heer	X				?			X			X					X	X	X	X									X	X	X	X	X	X		X	X	X	X	X	
Sphaerites alabamensis Berry		X	X	X																																				
Sterculia snowii tennesseensis Berry																					X																			
Tricalycites papyraceus Newberry		X	X					X																			X		X	X										
Tumion carolinianum Berry?																	X														X									
Widdringtonites reichii (Ettingshausen) Heer		X	X				X	X			X																	X	X	X			X	X		X				
subtilis Heer			X				X	X																					X	X		X	X							X
Zizyphus lamarensis Berry		X																									X													
laurifolius Berry																	X																							

THE FLORAS.

Phylum THALLOPHYTA.

Class FUNGI.

Order PYRENOMYCETES.

Genus SPHAERITES Unger.

[Genera et species plantarum fossilium, p. 37, 1850.]

Sphaerites alabamensis Berry, n. sp.

Plate V, figure 1.

When viewed megascopically these remains appear as elliptical or circular spots from 1 to 1.5 millimeters in diameter, each containing several darker dots which represent the spore groups. The margins of the leaf spots are well marked and not diffuse.

Sphaerites alabamensis was found in abundance upon various leaves, including those of *Platanus shirleyensis* Berry. It is plainly congeneric with the forms usually referred to this genus and very similar to *S. problematicus* (Knowlton) Knowlton from the Dakota sandstone of Kansas and *S. raritanensis* Berry from the Raritan formation of New Jersey. *S. problematicus*, however, is more irregular in outline and infests *Sterculia*, which is not the host of the Tuscaloosa species.

A great variety of fungi have the habit of the present form and produce leaf spots in the higher plants. As the microscopic characters, particularly of the spores, are relied upon for specific differentiation, the correct determination of fossil forms of this sort is impossible, and the name chosen must be regarded as constituting a purely form genus. Though remains of this sort are of little botanic interest, except to a certain type of narrow specialists, they have a considerable biologic significance in the evidence which they afford of the existence during the mid-Cretaceous of fungi of this order.

Occurrence: Tuscaloosa formation, Shirleys Mill, Glen Allen, Fayette County; gully in the Tuscaloosa, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Phylum BRYOPHYTA.

Class HEPATICAE.

Order JUNGERMANNIALES.

Genus JUNGERMANNITES Goeppert.

Jungermannites cretaceus Berry, n. sp.

Plate V, figures 2, 3.

Thallus creeping, foliose, dorso-ventral, with a stout flexuous axis that bears on its upper surface crowded overlapping ovate orbicular lobes of considerable consistency and about 2 millimeters or slightly less in length.

This unique form is unfortunately represented by only three specimens, two of which are figured. These have been submitted to Prof. A. W. Evans and Dr. M. A. Howe, authorities on the Hepaticae. Prof. Evans dissents from my opinion that the specimens represent a Cretaceous liverwort. Dr. Howe, not forgetting that the remains are problematic, sees a strong superficial resemblance to certain foliose and subfoliose liverworts, as for example, the genus *Chiloscyphus* of our Southern States or the tropical genus *Noteroclada*.

It must be admitted that the remains are not conclusive, but I know of no vegetative characters that can be shown by a fossil hepatic that are conclusive. They certainly impress the general student, who is less familar with the details of the living Hepaticae where complete material is available and who therefore does not expect impossible feats of preservation, as remarkably like existing foliose liverworts. Undoubted thalloid liverworts are well known in the Mesozoic, although represented by scant materials. Foliose forms are much rarer. Saporta[1] has described what he thinks is such a form from the Lower Cretaceous of Portugal as *Jungermannites vetustior*. There are several Tertiary species, including well-preserved and conclusive material from the Baltic amber.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Phylum PTERIDOPHYTA.

Order EQUISETALES.

Genus EQUISETUM Linné

Equisetum? sp. Berry.

A small fragment of what appears to be the stem of an *Equisetum* occurs in the collections from the big gully on the Snow place in Tuscaloosa County, Ala. It is 3.5 centimeters long and about 3 millimeters in diameter, with 10 to 12 prominent ribs. Nodes about 6 millimeters apart.

The material is entirely insufficient for specific characterization but is of interest as indicating the probable presence of this type of plant in the Tuscaloosa flora. The New Jersey Raritan species *Carpolithus pruniformis* New berry[1] also probably represents fossilized *Equisetum* tubers.

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[1] Saporta, Gaston de, Flore fossile du Portugal, p. 123, pl. 23, fig. 14, 1894.

Occurrence: Tuscaloosa formation, big gully on the Snow place, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Order LYCOPODIALES.

Genus LYCOPODIUM Linné.

Lycopodium cretaceum Berry?

Lycopodium cretaceum Berry, Am. Jour. Sci., 4th ser., vol. 30, p. 275, figs. 1-6, 1910.

These remains consist of fruiting spikes, loosely imbricated, of modified foliage leaves or bracts. The largest spike seen, which is nearly complete, is 5 centimeters in length and 5 millimeters in diameter, and is probably somewhat flattened, the bulk of the specimens indicating somewhat smaller dimensions. Axis stout. Bracts several-ranked, peduncled, with a cordate or retuse base and an abruptly narrowed, acute, recurved apex, with an entire margin, each bract subtending a large spheroidal sporangium which may possibly be reniform, although as preserved in the form of impressions in the clay it appears to be globular. There is considerable variation in size, the shorter and smaller spikes being less crowded and somewhat lax in appearance.

I have described this species from rather abundant and relatively well preserved material found in the Middendorf arkose member of the Black Creek formation of South Carolina, a somewhat later Cretaceous horizon than the occurrence here discussed, which is based upon poor material that was collected at Shirleys Mill from the lower part of the Tuscaloosa formation and is queried because of its unsatisfactory character.

Occurrence: Tuscaloosa formation, Shirleys Mill, Glen Allen, Fayette County, Ala.

Collections: U. S. National Museum.

Genus LYCOPODITES Brongniart.

Lycopodites tuscaloosensis Berry, n. sp.

Plate V, figures 4-7.

Slender, elongated fruiting axes, bearing relatively distant, spirally arranged, short and stout, acuminate and often recurved bracts, each subtending an axillary sporangium of considerable size.

The axes vary in diameter from 0.5 millimeter to 2 millimeters, and some are preserved for a length of 8 centimeters. The distance between successive bracts ranges from 3 to 6 millimeters, averaging nearer the smaller than the larger figure. The bracts are short and stout, curved or recurved, slightly flattened and sharply pointed. The supposed sporangia are badly preserved and are commonly wanting. They are ovoid in outline, broadest proximad, and are about 2 millimeters in diameter. They appear to be of considerable consistency and some specimens show longitudinal angles suggesting a comparison with the recent genus *Psilotum.*

These curious fossils are exceedingly abundant in the clays of the basal part of the Tuscaloosa formation at the Shirleys Mill locality, occurring sparingly at Glen Allen. Only two possible relationships can be suggested—one that they represent some angiospermic fruit axes and the other that they are lycopodiaceous. The evidence from the specimens, which are fairly well preserved, does not lend any support to the former view. I believe that the latter view is conclusive, although naturally their preservation as impressions in clay leaves much to be desired. I was at first disposed to refer them to *Psilotites*, but there is no positive evidence that the sporangia were bilocular or trilocular, unless their angled exterior may indicate that they were compound, and this feature may be due to compression of a sporangium of considerable consistency, such as these were. There is certainly a flexing of the axis and a slight swelling at the base of the sporangium that reminds one of *Psilotum*, but the subtending bract is simple and not forked as in *Psilotum*, although it is of the relative proportions and shape of a single fork of a *Psilotum* bract. Some of the axes without traces of sporangia are comparable to the main axes of *Psilotum* with reduced leaves, and there are no other indications of foliar parts in the fossils. The arrangement and spacing of the parts are distinctly more open than in any recent lycopodiums known to me, the supposed foliage is much more reduced, and the sporangia are relatively larger.

It is possible that the fossil represents an early Upper Cretaceous type intermediate in habit between *Lycopodium* and *Psilotum.* I know of no described fossils with which close comparisons can be made. The only similar form is that based on remains from the Cenomanian of Bohemia, which were identified by Velenosky[1] as fruit twigs of a *Myrica*, an identification which is very doubtful.

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[1] Newberry, J. S., The flora of the Amboy clays: U. S. Geol. Survey Mon. 26, p. 133, pl. 46, fig. 42, 1896.

Occurrence: Tuscaloosa formation, Shirleys Mill (common) and Glen Allen (rare), Fayette County, Ala.

Collection: U. S. National Museum.

Order FILICALES.

Family POLYPODIACEAE.

Genus CLADOPHLEBIS Brongniart.

Cladophlebis alabamensis Berry, n. sp.

Plate V, figure 8.

This species is based upon a single ultimate pinnule of a fern of the *Cladophlebis* type, which therefore fails to shed any light on the character of the frond as a whole, or on the shape of the normal pinnae and pinnules of the proximal part of the frond. It may be characterized as follows: Frond certainly bipinnate and probably tripinnate. Normal pinnae probably made up of numerous lanceolate falcate pinnules, each attached by its entire base. Pinnae pass distad into pinnatifid pinnules like the specimen preserved. These ultimate pinnules are linear-lanceolate in outline, about 3 centimeters in length and 4 millimeters in greatest width. The texture is coriaceous and the midrib stout. The margin is cut to form subopposite to alternate aquiline pointed lobes separated nearly to the midrib proximad but becoming gradually obsolete distad. The secondaries are fine and show for each lobe the typical venation of a normal *Cladophlebia* pinnule—that is, a midrib which sends off on either side at acute angles simple or dichotomously, once-forked veinlets which run directly to the margin.

This species is clearly distinct from previously described forms, although it suggests various Lower Cretaceous species, as, for example, *Cladophlebis albertsii*, *C. browniana*, *C. ungeri*, and *C. parva*, all of which have similar ultimate pinnules. It is closest perhaps to *C. browniana* and *C. parva*, both of which range from the bottom to the top of the Lower Cretaceous in the Maryland-Virginia area. There is a certain resemblance to various Cretaceous species that have been referred to the genus *Gleichenia*, but this resemblance is believed to be purely superficial.

Cladophlebis is essentially a form genus which is restricted at the present time to include only certain fern remains of Mesozoic age, although this type of frond is practically identical with those of some Paleozoic genera, as, for example, *Pecopteris*, and it can also be closely matched by a variety of Tertiary and living ferns.

Cladophlebis was proposed by Brongniart[2] in 1849 for those species which formed his section *Pecopteris neuropteroides*,[3] which he regarded as transitional between *Pecopteris* and *Neuropteris*. Certain of their characters were mentioned, but no formal diagnosis was attempted. The genus has been characterized by Saporta,[4] Schimper,[5] Seward,[6] and the present writer.[7]

Much difference of opinion has prevailed regarding the unity and the systematic position of the genus, Saporta[8] having long ago pointed out that Brongniart's Paleozoic species had nothing in common with those of the Mesozoic, and that the Liassic and Oolitic forms, those which the former author was discussing, give evidence of common characters. At the present time evidence is still lacking from such fructified remains as have been discovered of close relationship between all of the various species of *Cladophlebis*. Thus Heer discovered, in the Siberian Jurassic, fragments of the type of *C. whitbyensis* with soral characters which he compared with those of *Diplazium*, a subgenus of *Asplenium*,[9] and Schenk has figured fertile pinnules of the same type in the allied *Asplenites roesserti*.[10] Certain sepcimens of the Jurassic species *C. lobifolia* show that the sporangia in this species were apparently borne in semicircular pocket-like depressions on the edges of the fertile segments,[11] whereas the fructifications of *C. denticulata* are in the form of narrow, oblong sori parallel with the secondary veins and are compared by Seward[12] with the modern forms *Asplenium lugubre* and *Phegopteris decussata*. In his latest work on this subject he states that "there are fairly good grounds for the assertion that some at least of the fronds described under this name are those of Osmundaceae."[1] Zeiller[2] in 1910 described a species from the Wealden of Peru which he considers identical with or very close to *C. browniana*, in which the sporangia are biseriate, oval, and annulate as in the Schizaeaceae. These species are said to be very like those of the Jurassic genus *Klukia* of Raciborski. In 1890 Fontaine described 14 so-called species of *Aspidium* Swartz [*Dryopteris* Adanson], mostly fertile fronds from the Lower Cretaceous flora of the Potomac group. These leaves showed mostly large elliptical or reniform sori in rows on each side of the midvein, and located generally on the distal branch of a furcate vein, usually wanting in the apical part of the pinnule. These species were compared by this author with modern species of *Aspidium*, *Cystoperis*, *Polystichum*, and *Didymochlaena*. By careful comparison I have correlated the fertile specimens described as *Dryopteris* with the sterile *Cladophlebis* fronds of the same species in five of the types that are represented in the Potomac flora by sterile and fertile fronds.[3]

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[1] Velenovsky, Josef, Die Flora der böhmischen Kreideformation, pt. 2, p. 11, pl. 5, figs. 9-12, 1883.

[2] Brongniart, Adolphe, Tableau des genres de végétaux, p. 25, 1849.

[3] Brongniart, Adolphe, Histoire des végétaux fossiles, p. 320, 1828.

[4] Saporta, Gaston de, Paléontologie française, ser. 2, Végétaux, Plantes urassiques, vol. 1, pp. 298, 299, 1873.

[5] Schimper, W. P., Traité de paléontologie végétale, vol. 3, p. 503, 1874.

[6] Seward, A. C., Wealden flora, pt. 1, p. 88, 1894.

[7] Berry, E. W., Maryland Geol. Survey, Lower Cretaceous, p. 239, 1911.

[8] Saporta, Gaston de, op. cit., vol. 4, p. 357, 1888.

[9] Heer, Oswald, Flora fossilis arctica, vol. 4, p. 38, pl. 21, figs. 3, 4, 1877.

[10] Schenk, August, Die fossile Flora der Grenzschichten des Keupers und Lias Frankens, p. 51, pl. 7, figs. 7, 7a, 1867.

[11] Seward, A. C., The Jurassic flora, pt. 1, fig. 23, 1900.

[12] Idem, p. 141.

Though the foregoing facts are not in unison in regard to the systematic position of *Cladophlebis* they all point to the inclusion of the American species in the family Polypodiaceae, or what answered to this family in Lower Cretaceous time. It is quite possible that ferns of more than one subfamily of the Polypodiaceae, or, indeed, of other families, are included among the various described species of *Cladophlebis*. It need but be remembered how many unrelated modern ferns have fronds of the *Cladophlebis* type, as, for example, certain species of *Alsophila*, *Asplenium*, *Cyathea*, *Dryopteris*, *Gleichenia*, *Onoclea*, *Osmunda*, *Polypodium*, and *Pteris*, to cast doubt upon the botanic affinity of *Cladophlebis* species unless these are attested by a considerable body of evidence.

A larger number of species of *Cladophlebis* have been described, of which two species, according to Arber, occur in the "Permo-Carboniferous" of India. The genus appears in force in the Keuper and Rhaetic, with more than a dozen recorded species. Over a score are recorded during the Jurassic, certain types, such as *C. denticulata*, apparently becoming world-wide in their distribution. For the Lower Cretaceous Saporta has founded a large number of species based upon Portuguese material, and Fontaine has instituted a still larger number of American species. From the Potomac group of Maryland and Virginia the latter author recorded 23 different species, besides several varieties of *Cladophlebis*, all of which I have recently revised to form eight legitimate species.[4]

Occurrence: Tuscaloosa formation, big gully on the Snow place, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Genus DRYOPTERITES Berry.

Dryopterites stephensoni Berry.

Dryopterites stephensoni Berry, U. S. Geol. Survey Prof. Paper 84, p. 103, pl. 17, figs. 1, 2, 1914.

Fronds bipinnate or possibly tripinnate. Pinnules thick in texture, ovate or lanceolate in outline, ascending, merging toward the apex of the pinnae. A single vein enters each pinnule, branching from the rachis at an extremely acute angle and immediately breaking up into three branches, the upper usually remaining simple and running to the upper margin, the lower usually forking once and running to the lower lateral margin, and the middle dividing four or five times to form the main vascular system of the pinnule, the distal branches tend to remain simple and the proximal usually fork once. The Alabama specimens are infested with a leaf-spot fungus which simulate sori.

This species was recently described by me from the Upper Cretaceous of Georgia. It is quite distinct from any forms known from the Upper Cretaceous but suggests a comparison with various previously described forms, as, for example, the fern remains described by Debey and Ettingshausen from Aachen (Senonian) on the Prussian border as *Pteridolemma gymnorachis*.[5] Other forms which show a superficial resemblance to the one under consideration are those described by Kerner from Lesina, Dalmatia (Cenomanian), as various species of *Pachypteris*.[6]

Still other fern remains described as *Sphenopteris grevilloides* Heer,[7] *Grevillea tenera* Velenovsky,[1] and *Thyrsopteris grevilloides* Hollick,[2] and which range from the Kome beds of Greenland to the Upper Cretaceous of Marthas Vineyard (Magothy formation), are suggestive of the present fern in general aspect but are seen to differ both in outline and venation when careful comparisons are made. The modern genus *Dryopteris* Adanson (*Aspidium* Swartz) is composite and has between 400 and 500 species of wide geographic distribution in the existing flora. Fossil species, which were set apart from the modern genus as the genus *Dryopterites* by the writer in 1911, have been described from the Lower Cretaceous upward, the Upper Cretaceous records including *Dryopteris oerstedi* (Heer) Knowlton, from the Atane and Patoot beds of Greenland, and *Dryopteris kennerleyi* (Newberry) Knowlton, from Vancouver Island, neither of which appears to be closely related to the present plant. The form identified as *Dryopteris oerstedi* from the Patapsco formation of Virginia is *Cladophlebis browniana*.

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[1] Seward, A. C., Fossil plants, vol. 2, p. 345, 1910.

[2] Zeiller, C. R., Compt. Rend., vol. 150, p. 1488, 1910.

[3] Berry, E. W., op. cit., p. 239.

[4] Berry, E. W., op. cit., p. 239.

[5] Debey, M. H., and Ettingshausen, C. von, K. Akad. Wiss. Wien Denkschr., vol. 17, p. 234, pl. 7, figs. 21, 22, 1859.

[6] Herner, F., K.-k. geol. Reichsanstalt Jahrb., vol. 45, pp. 39 et seq., 1895.

[7] Heer, Oswald, Flora fossilis arctica, vol. 3, pt. 2, p. 34, pl. 11, figs. 10, 11, 1874.

Occurrence: Tuscaloosa formation, big gully on the Snow place, Tuscaloosa County, Ala. (collected by W. M. Fontaine). Ripley formation (Cusseta sand member), cut on the Central of Georgia Railway, 1½ miles northeast of Byron, Houston County, Ga. (collected by L. W. Stephenson).

Collections: U. S. National Museum.

Genus ASPLENIUM Linné.

Asplenium dicksonianum Heer.

Asplenium dicksonianum Heer, Flora fossilis arctica, vol. 3, pt. 2, p. 31, pl. 1, figs. 1–5, 1874; idem, vol. 6, pt. 2, pp. 3, 33, pl. 2, fig. 2; pl. 32, figs. 1–8, 1882.

Dawson, Roy. Soc. Canada Trans., vol. 1, sec. 4, p. 11, 1883; idem, vol. 3, sec. 4, p. 5, pl. 3, fig. 1, 1885; Canada Geol. Survey Ann. Rept., new ser., vol. 1, p. 76, 1886; idem, vol. 10, sec. 4, p. 91, 1892.

Lesquereux, The flora of the Dakota group, p. 24, pl. 1, fig. 1, 1892.

Newberry, The flora of the Amboy clays, p. 39, pl. 1, figs. 6, 7; pl. 2, figs. 1–8; pl. 3, fig. 3, 1896.

Ward, U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, p. 704, pl. 170, fig. 1, 1899; Jour. Geology, vol. 2, pp. 259, 261, 1894.

Fontaine in Ward, U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, p. 664, pl. 162, figs. 6–8, 1899 (not Fontaine, 1888).

Kurtz, Contribuciones á la palaeophytología argentina, III: Rev. Museo La Plata, vol. 10, p. 49 (1899), 1902.

Berry, Torrey Bot. Club Bull., vol. 38, p. 409, 1911; New Jersey Geol. Survey Bull. 3, p. 68, pl. 5, figs. 3, 4, 1911.

This species was described by Heer in 1874 from the Kome beds (Lower Cretaceous) of Greenland as follows:

> A. foliis triplicato-pinnatis, stipite firmo, rigido; pinnis primariis secundariisque ovato-lanceolatis, pinnulis anguste lanceolatis, inferioribus acute serratis, superioribus integerrimis, acutis.

It was subsequently identified by Heer from the much later Atane beds (Upper Cretaceous) of Greenland; Dawson reported it from a number of localities in the Kootenai formation (Lower Cretaceous) of British Columbia, and Fontaine and Ward described it from the Lower Cretaceous of the Black Hills. It is also reported by both Lesquereux and Ward from the Dakota sandstone and by Kurtz from Argentina. It seems very doubtful if these specimens can all be the same plant, and the geologic range alone suggests that the earlier and the later forms may be distinct. The Lower Cretaceous forms certainly suggest a relationship with those widespread types of sterile fronds variously identified as *Thyrsopteris* or *Onychiopsis*, and they may be compared with *Onychiopsis goepperti* (Schenk) Berry. Those of the Upper Cretaceous suggest *Anemia* rather than *Asplenium* and are much like an undescribed *Anemia* from the lower Eocene (Wilcox group) of the Mississippi embayment area, as well as the widespread Eocene species *Anemia haydenii* (Lesquereux) and *Anemia subcretacea* (Saporta) Gardner and Ettingshausen. However, in the absence of representative material from the different horizons, it seems unwise to attempt any segregation at the present time, and the synonymy is cited in full for the use of some future student who may have access to enough material to enable him to make an accurate revision and segregation of this so-called species. Attention should also be called to its resemblance to the form occurring in the Upper Cretaceous of Greenland, the Raritan formation of New Jersey, and the Tuscaloosa formation of Alabama, which goes by the name of *Dicksonia groenlandica* Heer, although the ground for considering it a *Dicksonia* is entirely inconclusive.

In addition to the localities enumerated above the present species is abundant in the Raritan formation of New Jersey and Maryland and material that is absolutely identical with the New Jersey Raritan material which I have seen, and with that from the Dakota sandstone, occurs in the lower part of the Tuscaloosa.

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[1] Velenovsky, Josef, Die Flora der böhmischen Kreideformation, Theil 4, p. 11, pl. 7, figs. 9, 14, 16, 1885.

[2] Hollick, Arthur, U. S. Geol. Survey Mon. 50, p. 31, pl. 1, figs. 10–13, 1907

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Family CYATHEACEAE.

Genus DICKSONIA Presl.

[Tentamen pteridographiae, etc., p. 135, 1836.]

Dicksonia groenlandica Heer.

Dicksonia groenlandica Heer, Flora fossilis arctica, vol. 6, Abt. 2, p. 23, pl. 35, figs. 8, 9, 1882; idem, vol. 7, p. 2, pl. 48, figs. 1-3, 1883.
Berry, New Jersey Geol. Survey Bull. 3, p. 66, pl. 4, fig. 1, 1911.
Dicksonia borealis Heer, Flora fossilis arctica, vol. 6, Abt. 2, p. 23, pl. 44, fig. 2, 1882 (not *D. borealis* Heer, 1878, a very different Jurassic species).
Sequoia heterophylla Velenovsky, Ward, in Smith, E. A., On the geology of the Coastal Plain of Alabama, p. 348, 1894 (not Velenovsky).
Anemia stricta Newberry, The flora of the Amboy clays, p. 38, pl. 3, figs. 1, 2, 1896.

Heer's description, published in 1882, is as follows:

> D. foliis bipinnatis, pinnulis erectis, oblongo-lanceolatis, basi attenuatis, integerrimis, nervis subtilissimis, nervillis angulo acuto egredientibus, erectis.

Both of Heer's types, which are here united with Newberry's species, are small fragments of ultimate pinnae, which their author confesses are very similar, a fact well brought out by a comparison of the figured specimens. The material from the middle part of the Raritan formation at Woodbridge, N. J., is more ample, and, as may be seen lower down on the frond, the pinnules become toothed and finely pinnatifid, a feature not seen in the Greenland material. There is slight reason, however, for doubting their identity. Newberry himself pointed out that the *Dicksonia borealis* of Heer was probably identical with his species from New Jersey. Although common at Woodbridge, N. J., this species has not been found elsewhere in the Coastal Plain except in the Tuscaloosa formation of Alabama. It is present in both the Atane and Patoot beds of Greenland.

In Alabama it does not appear to be common, and the specimens are rather fragmentary. In this State it is distinguishable with difficulty from *Sequoia heterophylla*, which is also present in the Tuscaloosa formation and with which Ward confused the present species. The two species are easily and sharply distinguished by the great difference in the characters of their venation.

Occurrence: Tuscaloosa formation, upper ravine and big gully on the Snow place, Tuscaloosa County; Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Family GLEICHENIACEAE.

Genus GLEICHENIA Smith.

Gleichenia delicatula Heer.

Gleichenia delicatula Heer, Flora fossilis arctica, vol. 3, Abt. 2, p. 54, pl. 9, figs. 11e, f; pl. 10, figs. 16, 17, 1874; idem, vol. 6, Abt. 2, p. 9, 1882.
Velenovsky, Die Farne der böhmischen Kreideformation, p. 7, pl. 3, figs. 12-14, 1888.
(?) Hollick, Torreya, vol. 2, p. 147, pl. 3, fig. 4, 1902.
Gleichenia micromera Heer. Newberry, The flora of the Amboy clays, p. 36, pl. 3, fig. 6, 1896.
Berry, New Jersey Geol. Survey Bull. 3, p. 66, 1911.

Heer's description, published in 1874, is as follows:

> Gl. fronde gracillima, dichotoma, bipinnata, rachi tenuissima, pinnis approximatis, patentibus, linearibus, pinnulis minutissimis, rotundatis.

This species is a very delicate and handsome type, with tiny rounded coriaceous pinnules close set and united to the rachis by their entire base, and with elongated linear pinnae not over 1 millimeter to 1.5 millimeters in width. It is separated with difficulty from the contemporaneous small pinnuled gleichenias, especially if the material comprises only the distal portions of the pinnae of these other forms. It was described from the Kome beds (Lower Cretaceous) of Greenland by Heer in the third volume of his Arctic Flora, where it is immediately followed by the description of *Gleichenia micromera*, which may represent the same plant, the sole stated difference being the ovate shape of the pinnules of *G. micromera*, which are not united to the rachis by their entire base. The occurrence of *Gleichenia micromera* in the Raritan is based upon the misidentification by Newberry of fragmentary specimens that are identical with those from the Tuscaloosa formation of Alabama. Both specimens have their pinnules united by their whole base and therefore belong to *Gleichenia delicatula* as defined by Heer. Similar remains are present in the Upper Cretaceous of the Cumberland coal field in Wyoming, according to Knowlton. They have also been reported in considerable abundance from the Cenomanian of Bohemia by Velenovsky.

The genus *Gleichenia* (including *Dicranopteris*) is a most interesting one. In the living flora it has about 25 species, widely distributed throughout the tropics of both hemispheres, subtropical eastern Asia, and the humid regions of the southern zone. The fossil species are equally numerous and widespread. Aside from those forms from the Paleozoic and older Mesozoic which have been referred to the Gleicheniaceae, which reference is not conclusive, the genus enjoyed a wide adaptive radiation during the lower and middle Cretaceous. In the Lower Cretaceous (Kome beds) of Greenland Heer has described 15 species of Gleichenia, some of which reach the interior of North America, but none apparently occur in the Atlantic Coastal Plain. By the middle Cretaceous several of these Greenland forms had become widespread, and identical species occur in such widely separated localities as Europe and Kansas, or Europe, Greenland, Wyoming, and New Jersey. Four of the Greenland species find their way south along the Atlantic Coastal Plain and four reach Europe, where several additional species have also been described. With the gradual change of Tertiary climates the Gleicheniaceae moved southward, the only American fossil species of that age being the doubtful *Gleichenia obscura* Knowlton from the Tertiary Esmeralda formation (Oligocene?) of Nevada. This southern movement probably continued until Pleistocene time, sending the Gleicheniaceae into the West Indies, along the Andes into South America, along the eastern Asiatic coast, and across southern Europe into Africa.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Family MARATTIACEAE (?).

Genus MARATTIA Swartz (?).

Marattia cretacea Velenovsky (?).

Marattia cretacea Velenovsky, Die Farne der böhmischen Kreideformation, p. 9, pl. 1, fig. 13, 1888.

Velenovsky's description, published in 1888, is as follows:

> Frond large and long, with a finely toothed margin, slender midrib and numerous slender once or more dichotomously forked lateral veins.

This species was described by Velenovsky in 1888 from a single specimen found in the Perucer clays near Melnik in Bohemia (Cenomanian). A small fragment indistinguishable from this specimen occurs in the clays of the Tuscaloosa formation at Glen Allen, Ala. It suggests very much the Lower Cretaceous remains usually referred to the form genus *Taeniopteris*, as, for example, *Taeniopteris nervosa* (Fontaine) Berry[1] from the Patuxent formation of the Atlantic Coastal Plain. The evidence for its reference to the genus *Marattia* is entirely inadequate and inconclusive.

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County, Ala.

Collection: U. S. National Museum.

Phylum SPERMATOPHYTA.

Class GYMNOSPERMAE.

Order CYCADALES (?).

Genus PODOZAMITES Friedrich Braun.

Podozamites marginatus Heer.

Plate VI, figure 1.

Podozamites marginatus Heer, Flora fossilis arctica, vol. 6, Abt. 2, p. 45, pl. 16, fig. 10, 1882 (not Berry, 1903).
Newberry, The flora of the Amboy clays, p. 44, pl. 13, figs. 5, 6, 1896.
Berry, Torrey Bot. Club Bull., vol. 38, p. 410, 1911; New Jersey Geol. Survey Bull. 3, p. 74, 1911.

Pinnules rather large, ranging from 15 to 20 centimeters in length, variable in width, which ranges from 1.5 to 3 centimeters, the Tuscaloosa specimens being of minimum rather than maximum dimensions. Apex and base pointed, the angle dependent on the width of the pinnules. Base somewhat thickened and more or less abruptly narrowed in wide forms. Veins parallel, very fine and numerous, 30 or more in number. Texture thin but probably coriaceous.

This species was described by Heer from the Atane beds of western Greenland and was illustrated by a single rather poor figure. It was tentatively identified by Newberry from the middle part of the Raritan formation of Woodbridge, N. J. The Alabama form is certainly identical with the New Jersey material, and the same species is present in the Raritan in Maryland. Whether these are identical with the type is not certain, although such identity is probable. I have recorded this same species from the Magothy formation of New Jersey,[2] but this material proves to be referable to the subsequently discovered genus

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[1] Berry, E. W., Maryland Geol. Survey, Lower Cretaceous, p. 293, pl. 77, fig. 1, 1911.

[2] Berry, E. W., New York Bot. Garden Bull., vol. 3, p. 99, pl. 46, figs. 1, 3, 1903.

Doryanthites of the Black Creek formation in North Carolina and homotaxial deposits in Georgia and Alabama.

Podozamites marginatus is exceedingly abundant at some outcrops near the base of the Tuscaloosa formation. It is represented to the exclusion of almost all other plant types near the top of the fossiliferous portion of the section in the big gully on the Snow place. The remains, like most of those represented at this outcrop, are very badly macerated and must have been thoroughly decayed before fossilization, being much split between the veins. Similar distorted fragments were mistaken by Fontaine for Lower Cretaceous forms of *Laricopsis*. The present species shows considerable similarity to the Lower Cretaceous species *Zamites tenuinervis* Fontaine, which is so common in the Patapsco formation of the Potomac River valley.

Occurrence: Tuscaloosa formation, Soap Hill, Bibb County; Snow place, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Genus CYCADINOCARPUS Schimper.

[Traité de paléontologie végétale, vol. 2, p. 208, 1870.]

Cycadinocarpus circularis Newberry.

Cycadinocarpus circularis Newberry, The flora of the Amboy clays, p. 46, pl. 46, figs. 1-4, 1896.
Smith, E. A., On the geology of the Coastal Plain of Alabama, p. 348, 1894.
Berry, New Jersey Geol. Survey Bull. 3, p. 79, 1911.

Discoid fruits almost circular in outline from 6 to 12 millimeters in diameter, sometimes slightly emarginate on one side at the point which Prof. Newberry believed to be the point of attachment but which is probably the distal micropylar extremity. As usually preserved, the impression shows two concentric circles 1 to 2 millimeters apart, the inner representing the outline of the inner seed coat and the outer layer the slightly fleshy external coat.

These fruits always occur detached and are present in considerable abundance in the middle part of the Raritan formation of New Jersey. Similar remains are recorded from the Tuscaloosa formation of Alabama, and they are also present in the Black Creek formation of North Carolina. As their name indicates, they are assumed to represent the fruit of some contemporaneous species of cycad.

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County, Ala.

Collection: U. S. National Museum.

Order CONIFERALES.

Genus CEPHALOTAXOSPERMUM Berry.

Cephalotaxospermum carolinianum Berry.

Cephalotaxospermum carolinianum Berry, Torrey Bot. Club Bull., vol. 37, p. 187, 1910.

Drupaceous fruits solitary (?), sessile, or with an extremely short and stout peduncle, ovid, somewhat pointed apically and inclined to become slightly cordate below, consisting of an outer fleshy layer and an inner bony layer, as in the Cycadales and Ginkgoales; the surface mammillated much as in the *Podocarpus elongata* but less markedly so. Bony endocarp ovate-acuminate, immersed in the apical part of the exocarp. Evidently the drupaceous fruits of some Cretaceous member of the Taxaceae, which finds its closest homology in the recent flora in the fruits of *Cephalotaxus* and certain species of *Podocarpus*. These drupes have the following dimensions, as preserved in a much flattened condition: Length 6 to 13 millimeters, averaging about 10 millimeters; breadth 5 to 10 millimeters, averaging about 8 millimeters; thickness about 3 millimeters; fruit in life probably almost circular in cross section. Peduncle short and stout, or wanting. Stone ovate-acuminate, lying in the apical part of the fleshy exocarp, with the beaked micropylar end reaching almost or quite to the apex. As preserved in a much flattened condition in the clays, these fruits tend to split into two parts, disclosing the bony endocarp or merely a cast of its cavity. The fleshy part of the fruit is carbonized and fails to show any histologic details. There is some evidence or at least a suggestion in some specimens of the remains of a micropylar canal. Away from the pointed apex, the exocarp is 1 to 2 millimeters in thickness, reaching a thickness of 3 millimeters at the chalazal end.

These fruits are very abundant at certain localities in the Black Creek formation in North Carolina, and they have been collected in the extension of this formation near Florence, S. C. In Alabama they have only been collected in the basal part of the Eutaw formation in Hale County.

Fruits referable to the Taxaceae are extremely rare in the fossil state, as are also remains of foliage which can be referred with certainty to this family. Both *Tumion* and *Cephalotaxopsis* from the Lower Cretaceous of Maryland and Virginia are founded upon foliage which seems referable with considerable certainty to this family, and these same strata in those States abound in the foliage referred to the genus *Nageiopsis*, which seems to be closely related to *Podocarpus*, so that there is considerable reason for expecting to find Upper Cretaceous representatives of the family in this same general region. Heer[1] described a leafy twig from the Patoot beds (Senonian) of Greenland, with a large solitary fruit which he called *Cephalotaxites insignis*, an identification which Solms-Laubach[2] seems to consider probable. Bertrand[3] has described carbonized seeds from the Aachenien of Tournay, Belgium, under the name of *Vesquia tournaissii*, which he considers, because of the arrangement of the vascular bundles, as intermediate between *Tumion* and *Cephalotaxus*. It certainly seems to be significant that remains of this sort occur at nearly homotaxial horizons in America, Europe, and Greenland.

None of the foregoing, however, are comparable with the present forms, although certain indefinite remains described by Lesquereux as *Inolepis* sp.,[4] are remotely suggestive of them. It is not believed, however, that they are congeneric.

The modern genus *Cephalotaxus* Siebold and Zuccarine, with four species, is confined to the China-Japan region, although it seems evident that it was much more widespread in former geologic times, and to it should probably be referred some of the leafy twigs included in the genus *Taxites* of Brongniart. Fruits of three species of *Cephalotaxus*, apparently identified correctly, are described by Kinkelin[5] from the upper Pliocene deposits of the Main Valley in Germany. The features which seem to indicate a closer relation with *Cephalotaxus* than with *Podocarpus* are the absence of the thickened peduncle of *Podocarpus* and the presence of foliage in the same beds with these seeds described by the writer as *Tumion carolinianum*[6] and which is of the same type as that of *Cephalotaxus*.

Occurrence: Eutaw formation (basal beds), 2 miles south of Havana, Hale County, Ala.

Collections: U. S. National Museum.

Genus PROTOPHYLLOCLADUS Berry.

[Torrey Bot. Club Bull., vol. 30, p. 440, 1903.]

Protophyllocladus subintegrifolius (Lesquereux) Berry.

Phyllocladus subintegrifolius Lesquereux, Am. Jour. Sci., 2d ser., vol. 46, p. 92, 1868; The Cretaceous flora, p. 54, pl. 1, fig. 12, 1874; The flora of the Dakota group, p. 34, pl. 2, figs. 1–3, 1892.

Protophyllocladus subintegrifolius (Lesquereux) Berry, Torrey Bot. Club Bull., vol. 30, p. 440, 1903; idem, vol. 31, p. 69, pl. 1, fig. 5, 1904; Johns Hopkins Univ. Circ., new ser., No. 7, pp. 89-91, fig. 6, 1907; New Jersey Geol. Survey Bull. 3, p. 98, pl. 9, 1911.

Hollick, The Cretaceous flora of southern New York and New England, p. 36, pl. 5, figs. 1–6, 1906.

Thinnfeldia lesquereuxiana Heer, Flora fossilis arctica, vol. 6 Abt. 2, p. 37, pl. 44, figs. 9, 10; pl. 46, figs. 11, 12a, b, 1882.

Hollick, New York Acad. Sci. Trans., vol. 2, p. 99, pl. 3, fig. 6, 1892.

Newberry, The flora of the Amboy clays, p. 59, pl. 11, figs. 1-17, 1896.

Thinnfeldia subintegrifolia (Lesquereux) Knowlton, U. S. Geol. Survey Bull. 152, p. 228, 1898.

Hollick, New York Acad. Sci. Ann., vol. 2, pp. 58, 419, pl. 3, figs. 4, 5, pl. 36, fig. 6, 1898; New York Bot. Garden Bull., vol. 2, p. 403, pl. 41, figs. 13, 14, 1892.

Leaves oblong to linear in outline and coriaceous in texture, from 3 to 17 centimeters in length by 0.6 centimeter to 3 centimeters in width. Apex usually obtuse, rarely pointed. Base decidedly and narrowly cuneate to the short petiole. Margins entire below, above obtusely dentate or undulate, with a few teeth which are acute. Midrib stout below, becoming attenuated above and commonly disappearing some distance below the apex. Laterals numerous, close, immersed; they branch at an angle of about 20°, running nearly straight and approximately parallel to the margin, in places forking. Stomata scattered on both surfaces, with typical guard cells.

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[1] Heer, Oswald, Flora fossilis arctica, vol. 7, p. 10, pl. 53, fig. 12, 1883.

[2] Solms-Laubach, H., Fossil botany, p. 61, 1891.

[3] Bertrand, C. E., Soc. bot. France Bull., vol. 30, p. 293, 1883.

[4] Lesquereux, Leo, in Hayden, F. V., U. S. Geol. and Geol. Survey Terr. Ann. Rept. for 1874, p. 337, pl. 4, fig. 8, 1876; The Cretaceous and Tertiary floras, p. 33, pl. 1, fig. 8, 1883.

[5] Engelhardt, Hermann, and Kinkelin, T., Senckenberg. naturf. Gesell Abh., vol. 293, p. 194, pl. 23, figs. 9–13, 1908.

[6] Berry, E. W., Am. Jour. Sci., 4th ser., vol. 25, pp. 382–386, figs. 1–3, 1908.

This widespread species ranges in considerable abundance from Greenland (Atane beds) to New Jersey (Raritan and Magothy formations) and west to Kansas and Nebraska (Dakota sandstone). It was originally referred to *Phyllocladus* by Lesquereux, and his type is almost identical with certain phylloclads of modern members of this genus. Subsequently discovered remains from Kansas are considerably larger than the type, as are also a number of the Greenland specimens. Some of the Raritan forms have a somewhat different aspect, being long and narrow; some of the margins are entire, but many of them are more or less sharply toothed.

Much controversy has centered around these forms and especially around the older Mesozoic forms referred to the genus *Thinnfeldia* Ettingshausen, to which these later forms were once referred. That genus has been referred successively to the conifers, the ferns, and the cycads. There has never been much doubt that the later forms were gymnospermous. I can positively affirm this conclusion, and also that they are true phylloclads and not leaves in the strict morphologic sense.

Whether or not they are closely related to the modern genus *Phyllocladus* is still in doubt, although there are some excellent arguments for such a relationship. Though fossil remains of undoubted relationship to *Phyllocladus* are extremely rare, Gothan[1] has described wood of a similar type from the Jurassic of the east coast of Greenland under the name of *Phyllocladoxylon*. The present species has not heretofore been found in the Coastal Plain south of the New Jersey area, being apparently replaced in the Magothy formation of Maryland by an allied species, *Protophyllocladus lobatus* Berry,[2] which is a very abundant form in the Middendorf arkose member of the Black Creek formation of South Carolina. The Alabama remains consist of scarce fragments of the proximal parts of phylloclads and may possibly represent *Protophyllocladus lobatus*, although they are more like *Protophyllocladus subintegrifolius*. Characteristic remains of the latter have recently been sent to me from Sakhalin Island by M. Kryshtofovich, a Russian paleobotanist.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Genus CUNNINGHAMITES Presl.

Cunninghamites elegans (Corda) Endlicher.

Cunninghamia elegans Corda in Reuss, Versteinerungen der böhmischen Kreideformation, pt. 2, p. 93, pl. 49, figs. 29–31, 1846.

Cunninghamites elegans (Corda) Endlicher, Synopsis Coniferarum, p. 305, 1847.

Berry, U. S. Geol. Survey Prof. Paper 84, p. 106, 1914.

I have recently discussed the occurrence of this form in the Eastern Gulf Cretaceous in the paper cited.

Occurrence: Ripley formation (Cusseta sand member), near Byron, Houston County, Ga.

Collection: U. S. National Museum.

Genus DAMMARA Lamarck.

[Encyclopédie méthodique, vol. 2, p. 259, 1786.]

Dammara borealis Heer.

Dammara borealis Heer, Flora fossilis arctica, vol. 6, Abt. 2, p. 54, pl. 37, fig. 5, 1882.

Velenovsky, Květena českého cenomanu, vol. 7, pl. 1, figs. 28, 29, 1889.

Hollick, New York Acad. Sci. Trans., vol. 12, p. 31, pl. 1, fig. 17, 1892; New York Bot. Garden Bull., vol. 2, p. 402, pl. 41, fig. 6, 1902; The Cretaceous flora of southern New York and New England, p. 37, pl. 2, figs. 2–11 (part), 12–26 (part), 27a, 1907.

Newberry, The flora of the Amboy clays, p. 46, pl. 10, fig. 8, 1896.

Berry, New Jersey Geol. Survey Bull. 3, p. 80, 1911.

——— (not named) Hitchcock, Final report on the geology of Massachusetts, vol. 2, p. 430, pl. 19, figs. 4, 5, 1841.

Heer's description, published in 1882, is as follows:

> D. strobilorum squamis coriaceis, radiatum sulcatis, 22 mm. latis, apice obtuse rotundatis, apiculatis, basi attenuatis.

Scalelike organisms from 1 centimeter to 2 centimeters or possibly more in length, rounded distally and showing in some specimens a slightly emphasized apiculate point. Greatly expanded laterally in the upper part to a breadth reaching 2.5 centimeters, abruptly contracted at or about the middle to a cuneate or straight-margined flat peduncle about 5 millimeters in width, with numerous resin canals, approximately parallel with the lateral margins and dying out proximad, filled with an amberlike substance.

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[1] Gothan, Walter, K. svenska Vet.-Akad. Handl., vol. 42, No. 10, 1907.

[2] Berry, E. W., Torrey Bot. Club Bull., vol. 38, p. 403, 1911.

Remains of this species were described and figured by Hitchcock in his account of the organic remains found at Gay Head, Marthas Vineyard, as long ago as 1841. He did not name them but remarks: "It seems to me very obvious that these remains must be the seed vessels of some coniferous plants." In 1882 Heer found similar forms in the material from the west coast of Greenland and named and described them, as well as two other very similar forms, and definitely recognized their relation to *Dammara*. Subsequently, they have been recorded from the European Cenomanian by Velenovsky, Krasser, and Beyer, from the Raritan formation of New Jersey by Newberry, and from Long Island and Staten Island by Hollick. They are abundant in the middle part of the Raritan at Woodbridge, N. J., and occur in the upper part of the Raritan (at the same horizon as the beds at South Amboy, N. J.) immediately across the Arthur Kill on Staten Island.

The writer has found these scales in the Matawan formation of Maryland and in the Black Creek formation of North Carolina. They have not yet been detected in the Cretaceous deposits of South Carolina or Georgia and are not common in the Tuscaloosa formation, the only known locality being the one cited from western Alabama where this species is very sparingly represented.

Similar remains have been considered by Heer, White, Krasser, and others as representing the fruits of *Eucalyptus*, but it seems obvious that their relations are definitely with the araucarian conifers.

Occurrence: Tuscaloosa formation, upper ravine and big gully on the Snow place, Tuscaloosa County; Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Genus BRACHYPHYLLUM Brongniart.

[Prodrome d'une histoire des végétaux fossiles, p. 109, 1828.]

Brachyphyllum macrocarpum formosum Berry.

Plate V, figure 9.

Brachyphyllum macrocarpum Berry, Torrey Bot. Club Bull., vol. 37, p. 183 (not Newberry, 1896), 1910.

?*Brachyphyllum macrocarpum* Berry, idem, vol. 38, p. 420, 1911.

Brachyphyllum macrocarpum formosum Berry, idem. vol. 39, p. 392, pl. 30, 1912.

Slender elongated twigs, pinnately branched, covered with medium-sized, crowded, appressed leaves, spirally arranged. Leaves bluntly pointed, relatively smooth, thick.

In the consideration of the various specimens that have been referred to *Brachyphyllum macrocarpum* a very considerable variation within certain fixed limits is at once obvious. This variation is usually one of size, the more slender specimens being at the same time more elongated and smoother. This feature has been frequently noted by the writer and is commented upon by Knowlton,[1] who in discussing the younger forms from Wyoming suggests that the species on the verge of extinction became smaller in its proportions. In studying the material from the South Atlantic and Gulf States I noticed a constant difference in size. This difference may reflect a slight difference in climatic conditions, and all the forms may be interpreted as the variations of a single species; in fact, Newberry's figure from the Raritan formation in New Jersey [2] is approximately the same size as the forms from the Montana group of the West and is associated with the normal stout, club-shaped type. That the variety has no particular stratigraphic significance is indicated by its abundance in beds as old as the lower part of the Tuscaloosa and its presence in the Woodbine sand of Lamar County, Tex.

In general, however, the present variety occurs at later and more southern horizons than the type. This difference might be ascribed to the fact that only the slender terminal twigs are preserved, but such an explanation is regarded as improbable, for the same reasoning should hold good for the areas where only thicker twigs have been found.

The remains are usually much macerated and broken, and the immediate cause for the recognition of a new variety was the discovery of a relatively large specimen from the Magothy formation of Maryland, which showed such striking unlikeness to the type that separation was demanded and specific differentiation was even considered. In view, however, of the occurrence of both forms in association in Maryland and the well-known variation of not only the type but of coniferous foliage in general, it seemed wiser to consider the present form as a variety of the type, which as time progressed supplanted it to a large extent, if not altogether.

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[1] Knowlton, F. H., U. S. Geol. Survey Bull. 163, p. 29, pl. 4, figs. 5, 6, 1900.

[2] Newberry, J. S., U. S. Geol. Survey Mon. 26, pl. 7, fig. 7, 1896.

The new specimen from Maryland shows the terminal part of two approximately parallel and curved twigs, about 12 centimeters in length, united proximad. These twigs in their thickest portion are only 6 millimeters in diameter. At intervals of 3 to 5 millimeters subopposite lateral branches are given off in a pinnate manner. These branches are relatively much elongated, curved, and slender, averaging about 4 centimeters in length by 2 millimeters in diameter, bluntly pointed, and not tapering to any appreciable extent. They have been occasionally observed to fork pseudodichotomously, and some of them give off toward their distal ends tiny lateral branchlets less than a centimeter in length and about a millimeter in diameter.

The general proportions are thus decidedly different from the supposed parent type. The leaves are slightly smaller and smoother and somewhat more elongated in their relative proportions, at the same time lacking the apical papilla and the convergent striae. The form is much more graceful than the type in appearance and in its general aspect suggests the Lower Cretaceous genus *Arthrotaxopsis* of Fontaine.

Though tiny species of *Brachyphyllum* like *Brachyphyllum microcladum* Saporta, of the Neo-Jurassic, have been described, the new variety is even more slender than *Brachyphyllum gracile* Brongniart, of the Jurassic. The most closely allied form known appears to be one from the Albian of Buarcos in Portugal described by Saporta [1] as *Brachyphyllum obesiforme elongatum*. There is also considerable resemblance to *Brachyphyllum crassicaule* Fontaine, of the Patapsco formation in Maryland and Virginia.

Remains of this new variety are not at all uncommon in the Tuscaloosa formation, where they range from a horizon near its base in Fayette County up into the basal portion of the Eutaw formation in Hale County and also just east of Chattahoochee River in Georgia. It also occurs in the Magothy formation of Maryland and in the Woodbine sand of Texas.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; Whites Bluff, Greene County, Ala. Eutaw formation (basal beds), 2 miles south of Havana, Hale County, Ala.; McBrides Ford, Chattahoochee County, Ga.

Collections: U. S. National Museum.

Genus PROTODAMMARA Hollick and Jeffrey.

[Am. Naturalist, vol. 40, p. 199, 1906.]

Protodammara speciosa Hollick and Jeffrey.

Protodammara speciosa Hollick and Jeffrey, Am. Naturalist, vol. 40, p. 199, pl. 1, figs. 5–13; pl. 2, figs. 1–5, 1906; New York Bot. Garden Mem., vol. 3, p. 46, pl. 4, figs. 1–11; pl. 10, figs. 1–3; pl. 14, figs. 1, 4, 5; pl. 15, figs. 1–6; pl. 16, fig. 1, 1909.

Dammara microlepis Hollick (non Heer), New York Acad. Sci. Ann., vol. 11, p. 57, pl. 3, figs. 9a, b, 1898.

Dammara minor Hollick. The Cretaceous flora of southern New York and New England, p. 40, pl. 2, figs. 35–37, 1906.

The description by Hollick and Jeffrey, published in 1906, is as follows:

> Organisms consisting of kite-shaped cone scales, from 4 to 6 millimeters long by 4 to 6 millimeters broad above, abruptly narrowed from about the middle to the base, rounded, incurved, and apiculate above; resin ducts five or more, extending down the lower surface of the limb; seed scars three in number, crescentically arranged above the middle and approximately in the broadest part of the scale, with the central one higher up than the laterals.

These interesting cone scales, of which structural material has been described by Hollick and Jeffrey from the Raritan formation at Kreischerville, Staten Island, and which is recorded by Hollick from the Magothy formation of Block Island, occurs at Shirleys Mill in the Tuscaloosa formation. The dimensions of the specimens from the Tuscaloosa are 4 by 5 millimeters. They are preserved in a plastic clay and show a lunate distal boss, the short apical point being entirely obscured, as it is in most of the similarly preserved specimens figured by Hollick.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

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[1] Saporta, Gaston de, Flore fossile du Portugal, p. 176, pl. 31, fig. 14, 1894.

Genus GEINITZIA Endlicher.

Geinitzia formosa Heer.

Geinitzia formosa Heer, Zur Kreideflora von Quedlinburg, p. 6, pl. 1, fig. 9; pl. 2, 1871.
Newberry, The flora of the Amboy clays, p. 51, pl. 9, fig. 9, 1896.
Hollick, New York Acad. Sci. Trans., vol. 16, p. 129, pl. 12, figs. 1, 2, 1897.
Knowlton, U. S. Geol. Survey Bull. 163, p. 28, pl. 5, figs. 1, 2, 1900.
Berry, New York Bot. Garden Bull., vol. 3, p. 57, 1903; Torrey Bot. Club Bull., vol. 31, p. 68, figs. 2, 3, 1904; New Jersey Geol. Survey Bull. 3, p. 97, 1911.
Geinitzia sp., Newberry, Lyceum Nat. Hist. New York City Proc., 2d ser., p. 10, 1873.
Sequoia reichenbachi (Geinitz) Heer. Lange, Deutsche geol. Gesell. Zeitschr., vol. 42, p. 660, 1890 (in part).
Stanton and Knowlton, Geol. Soc. America Bull., vol. 8, p. 137, 1897.
Sequoia gracillima (Lesquereux) Newberry, The flora of the Amboy clays, pl. 9, figs. 1-3, 1896 (not foliage described on p. 50).
Berry, New York Bot. Garden Bull., vol. 3, p. 57, pl. 48, figs. 21, 22, 1903; Torrey Bot. Club Bull., vol. 31, p. 69, pl. 2, 1904; Am. Geologist, vol. 34, pl. 15, 1904; Torrey Bot. Club Bull., vol. 32, p. 44, 1905; idem, vol. 33, p. 165, 1906; New Jersey Geol. Survey Ann. Rept. State Geologist for 1905, p. 139, 1906.

Heer's description, published in 1871, is as follows:

> Strobili ovato-cylindrici, squamis rachi validae spiraliter insertis, apice peltatis, disco concavo, margine crenato, toroso; semina sub quavis squama quatuor (?), squamarum stipite crasso inserta, striata.
>
> G. formosa, ramulis elongatis, virgatis, foliis omnino tectis, foliis subfalcatis, angustis, apice valde attenuatis, uninerviis, ramis adultis pulvinis rhombeis obtectis.

The American occurrences of cones of this species have heretofore been referred to *Sequoia gracillima* Newberry, a composite made up of *Geinitzia* cones and *Widdringtonites* foliage. These cones are exceedingly abundant in the Magothy formation at Cliffwood Bluff, N. J., where those that are more or less pyritized are washed out of the clays by storms and high tides. When preserved as flattened lignitic inclusions they are somewhat different in appearance, and it is believed that lignitic material of this species is the basis for the Raritan forms which were identified as *Microzamia gibba* Corda by Newberry.[1] A doubtful fragment and another somewhat more definite cone are contained in the Tuscaloosa collections made by me at Shirleys Mill, Ala. The foliage, which resembles somewhat that of *Sequoia reichenbachi* (Geinitz) Heer, as well as that of *Cunninghamites squamosus* Heer, shows rather thick twigs with slender curved needle leaves interspersed with small scale-like leaves. It has been found at a number of localities in this country and is represented in the Tuscaloosa formation by a single doubtful specimen.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Genus ARAUCARIA Jussieu.

Araucaria bladenensis Berry.

Plates IX, X.

Araucaria bladenensis Berry, Torrey Bot. Club Bull., vol. 35, p. 255, pls. 12-14, figs. 1-3, 1908.
(?) Berry, idem, vol. 38, p. 405, 1911.

Foliage dense, phyllotaxy spiral, leaves decurrent, coriaceous, ovate-lanceolate, about 1.6 by 8 centimeters, the base rounded, apex thickened, cuspidate; veins immersed, averaging 16 in number, straight, parallel, stomata small, in rows on ventral surface.

Leaves ranging from 1 centimeter to 2.8 centimeters in length by 0.5 centimeter to 1.2 centimeters in width, averaging 1.6 centimeters by 0.8 centimeter, obovate in outline, with a broad rounded base narrowing abruptly and decurrent; the blade broadest about one-third of the distance from the base, above which point it narrows sharply to a thickened cuspidate tip; phyllotaxy spiral; leaf substance represented by a thick sheet of lignite about 0.5 millimeter thick, in which the veins are immersed. These veins average 14 to 16 in number, although in a few specimens there are as many as 20; they are stout, incurved at the base (forking not observed), but become parallel and run directly upward until they abut against the leaf margin—that is, they are not convergent toward the tip of the leaf. In spite of their striking megascopic appearance their microscopic structure is not preserved.

One or two rather inferior specimens, which are in a more argillaceous matrix, show the arrangement and outlines of the stomata, which are broadly ovate in shape with very thin guard cells (at least when viewed on the surface). They are arranged in somewhat irregular rows on the ventral surface of the leaf, the number of rows between the two veins being usually four. Aside from the foregoing facts, the preservation is such that no other details can be made out.

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[1] Newberry, J. S., The flora of the Amboy clays: U. S. Geol. Survey Mon. 26, p. 45, pl. 12, figs. 6, 7, 1896.

This species is most remarkably similar to the living *Araucaria bidwilli* of the Australian region. This resemblance in form, habit, and stomatal characters, reinforced by the occurrence of characteristic araucarian cone scales in the same beds at certain localities, renders the identification reasonably conclusive.

The most nearly related form seems to be *Araucarites ovatus* described by Hollick[1] from the "Cliffwood clay" (Magothy formation) of New Jersey, which differ merely by their larger size, absence of basal characters, and much less pointed tips; in fact, if the two were found in closer association or if in the abundant material any specimens had approached *Araucarites ovatus* in size I would be disposed to consider them as the variants of a single species. It seems better, however, to institute a new species, as the leaves in the material from the southern Coastal Plain are sufficiently and uniformly different enough to be readily recognized, and there is the further possibility that the New Jersey species may be more or less closely related to the modern genus *Dammara* rather than *Araucaria*.

A European form, which must surely be considered as a nearly related congener of *Araucaria bladenensis*, is Saporta's *Araucaria toucasi* described from the Turonian of Beausset near Toulon, France.[2] This species is strikingly similar to the American species in every respect and is likewise closely allied, in appearance at least, to the living *Araucaria bidwilli* of Australia.

Kerner[3] records *Pachyphyllum (Pagiophyllum) rigidum* Saporta and *Pachyphyllum (Pagiophyllum) araucarium* Saporta from the Cenomanian of Lesina, an island in the Adriatic off the coast of Dalmatia, both being originally Jurassic species from the French Coralline of Verdun. Both are very similar to the American species and are about the same age. The probable identity of Cenomanian and Coralline species seems extremely doubtful, and both of Kerner's species should undoubtedly be considered as new species of *Araucaria*, and nearly related to if not identical with such Cretaceous forms as *Araucaria bladenensis* or *Araucaria toucasi*. This species is exceedingly common in and characteristic of the Black Creek formation in North Carolina. In South Carolina it is found in the extension of these beds. It is present in the lower part of the Eutaw formation and in later Cretaceous deposits in western Georgia and along Chattahoochee River. Careful search has failed to discover this species in the fossiliferous plant beds of western Alabama of Tuscaloosa age, but it is present in great abundance at the very base of the Eutaw deposits in Hale County. Recent collections have shown it to be present in the Magothy formation in Maryland.

Occurrence: Eutaw formation (basal beds), 2 miles south of Havana, Hale County, Ala.; Chimney Bluff, Chattahoochee County, Ga. Ripley formation (Cusseta sand member), Buena Vista, Marion County, Ga.

Collections: U. S. National Museum.

Araucaria jeffreyi Berry.

Araucaria jeffreyi Berry, Torrey Bot. Club Bull., vol. 35, p. 258, pl. 16, 1908; U. S. Geol. Survey Prof. Paper 84, p. 105, 1914.

These cone scales were completely described in the papers cited and need not be discussed here.

Occurrence: Eutaw formation, Chimney Bluff, Chattahoochee County, Ga. Ripley formation (Cusseta sand member), near Byron, Houston County, Ga.

Collections: U. S. National Museum.

Genus ANDROVETTIA Hollick and Jeffrey.

Androvettia carolinensis Berry.

Plate VII, figures 1-10.

Androvettia carolinensis Berry, Torrey Bot. Club Bull., vol. 37, p. 183, pl. 19, figs. 1-6, 1910.

Remains of leafy twigs, consisting of much flattened, phylloclad-like, opposite twigs, the leaves on the flat surfaces being reduced to mere points and not visible without magnification, the marginal leaves strictly opposite, with a regular alternation of a blunt dentate lobe, which probably represent reduced lateral twigs and a serrate point, the two fused proximad. Venation, consisting of immersed vascular bundles, not seen except in a strong transmitted light. The midvein is strong and straight, the visible lateral veins, which are the midveins of the coalesced leaves and lateral twigs, are pinnately arranged and single in the pointed leaves. In the round lobes they are usually dichotomously forked, but in this form the marginal lobes probably represent coalesced leaves of reduced lateral twigs. Their angle of divergence is greater than in *Androvettia statenensis* Hollick and Jeffrey and the whole arrangement is more distinctly cyclic in character. The texture is very coriaceous; the epidermal cells are, however, large in size, though with thick walls. The stomata are fairly numerous, apparently on both surfaces, and consist of the familiar sausage-shaped guard cells surrounded by four accessory cells.

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[1] Hollick, Arthur, New York Acad. Sci. Trans., vol. 16, p. 128, pl. 12, figs. 3a, 4, 1897.

[2] Saporta, G. de, Le monde des plantes avant l'apparition de l'homme, p. 198, fig. 27, 1879.

[3] Kerner, F. von, K.-k. geol. Reichsanstalt Jahrb., Band 45, p. 49, pl. 4, figs. 1, 3, 1895.

The general appearance of this species is even more fernlike than is the type of the genus, one reason being its smaller size and the absence in the collected material of the supposed male aments found in connection with some specimens of the Staten Island species. The present species was described by the writer from the exposures of the Black Creek formation on Tar River in North Carolina and is considerably younger than the Staten Island form.

This remarkable genus was erected by Hollick and Jeffrey[1] for the reception of a single species discovered recently in the upper part of the Raritan formation near Kreischerville, Staten Island, and these authors content themselves with a very good account of this species and refrain from framing a generic diagnosis.

These remains are all entirely fernlike in superficial appearance, uniformly coriaceous in texture, and from the details of their external characters and internal structure are indubitable gymnosperms of the order Coniferales. Their positive reference to the Araucarineae by Hollick and Jeffrey will, however, undoubtedly be questioned by many students. The North Carolina remains are not common and are confined to a single locality on Tar River. The lateral leaves along the edges of phylloclad-like twigs are markedly opposite, but the scale leaves on its flat surfaces are much more reduced than in *Androvettia statenensis* and can not be made out at all except in microscopic preparations of the epidermis, when they are seen to be reduced to mere points of termination of certain leaf traces. The lateral twigs are strictly opposite, as is the course of the vascular bundles, which consist of a regular alternation of opposite simple bundles and dichotomously forked bundles. The remains of a third species described by the writer as *Androvettia elegans* and collected from the basal part of the Eutaw formation in western Georgia, vary from *Androvettia statenensis* in the other direction and scarcely merit the term phylloclad-like; the leaves both marginal and surficial are opposite and well developed, very regular, with a vascular arrangement like that of the present form. They are distichous and opposite on a naked stem, which is thus more fernlike in appearance than either of the other two species. As the anatomy of these forms has not yet been studied the reader is referred to the memoir cited above, where the histology of the Staten Island form is discussed.

Regarding the systematic position of this genus, as already remarked, their relationship with the Araucarian group of conifers is questionable. They seem clearly distinct from *Phyllocladus*, and they are equally distinct from the various species of *Protophyllocladus* which have been recorded from the Raritan and the later Cretaceous formations of North America. They seem equally distinct from *Thinnfeldia* but may eventually prove to be related to *Moriconia*.

The Mississippi occurrence of this species is based upon fragmentary but characteristic specimens which are even smaller and more broken than is the type material from North Carolina. When the extremely coriaceous nature of this foliage and its almost complete maceration are considered in connection with its known range of about 600 miles in an air line and almost twice that distance along the Upper Cretaceous coast line, there seems to be a plausibility in attributing its scarcity and absence in the intervening region to its having lived in areas remote from those in which sediments were being deposited. The broken condition of the remains would thus be due to the length of time they had been in the water in their stream journey from their inland and possibly also upland habitat.

Occurrence: Tuscaloosa formation, cut on Southern Railway, 1⅝ miles east of Iuka,

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[1] New York Bot. Garden Mem., vol. 3, p. 22, 1909.

Tishomingo County, Miss. (collected by L. W. Stephenson).

Collection: U. S. National Museum.

Androvettia elegans Berry.

Androvettia elegans Berry, U. S. Geol. Survey Prof. Paper 84, p. 103, pl. 18, figs. 1-10, 1914.

This form is allied to *Androvettia carolinensis* and was recently described by the writer in the publication cited.

Occurrence: Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga.

Collection: U. S. National Museum.

Genus ABIETITES Hisinger.

Abietites foliosus (Fontaine) Berry.

Leptostrobus foliosus Fontaine, The Potomac or younger Mesozoic flora, p. 230, pl. 101, fig. 4; pl. 103, fig. 5; pl. 104, fig. 1, 1889; Status of the Mesozoic floras of the United States, p. 482, 1905.

Abietites foliosus (Fontaine) Berry, U. S. Nat. Mus. Proc., vol. 40, p. 314, 1911; Maryland Geol. Survey, Lower Cretaceous, p. 408, 1911.

Laricopsis longifolia Fontaine, The Potomac or younger Mesozoic flora, p. 233, pl. 102, figs. 7, 8; pl. 103, figs. 2, 3; pl. 165, fig. 4; pl. 168, figs. 5, 6, 1889; U. S. Nat. Mus. Proc., vol. 16, p. 268, pl. 36, fig. 9, 1893 (?); Status of the Mesozoic floras of the United States, p. 312, pl. 73, figs. 11, 14, 1905.

Leaves long and slender, 0.5 to 1 millimeter in width, full length not seen, at least several centimeters, much crowded; seen to be in bundles, where the preservation is fairly good, on stout, dichotomously forked twigs.

This species is clearly distinct from the other species of *Abietites*. It is not fully characterized because of the poorness of preservation, as evinced by the fact that the leaves are detached in a number of the specimens collected. The forms which were the basis for *Laricopsis longifolia* Fontaine have been united with the species, as they are indistinguishable and probably identical in character.

This species occurs in both the Patuxent and Patapsco formations of the Potomac group of Virginia, and it has also been recorded from the Kootenai formation of Montana. The fragment from the Trinity group of Texas, which Fontaine identified with such certainty, is, in the writer's judgment, absolutely untrustworthy. Characteristic remains are common at a single locality in the Tuscaloosa formation. Their significance in correlation is somewhat minimized, however, by the occurrence in the Magothy formation of remains very similar to these which I have described as *Pinus delicatulus*.[1] They may be compared with the foreign material described by Heer as *Pinus quenstedti*.

Occurrence: Tuscaloosa formation, big gully and upper ravine on the Snow place, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Genus SEQUOIA Endlicher.

[Synopsis coniferarum, p. 197, 1847.]

Sequoia reichenbachi (Geinitz) Heer.[2]

Plate VI, figure 2.

Araucarites reichenbachi Geinitz, Charakteristik der Schichten und Petrekfakten des sächisch-böhmischen Kreidegebirges, pt. 3, p. 98, pl. 24, fig. 4, 1842.

Sequoia reichenbachi (Geinitz) Heer, Flora fossilis arctica, vol. 1, p. 83, pl. 43, figs. 1d, 2b, 5a, 1868.

Fontaine, The Potomac or younger Mesozoic flora, p. 243, pl. 118, figs. 1, 4; pl. 119, figs. 1-5; pl. 120, figs. 7, 8; pl. 122, fig. 2; pl. 167, fig. 5, 1889.

Nathorst, in Felix and Lenk, Beiträge zur Geologie und Paleontologie der Republik Mexico, p. 52, figs. 4, 5, 1893.

Fontaine, in Ward, U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, p. 674, pl. 165, figs. 1, 2; pl. 166, fig. 1, 1899; Status of the Mesozoic floras of the United States, pp. 177, 263, 281, 544, pl. 55, figs. 7, 8; pl. 69, figs. 4, 5, 1905.

Lesquereux, The Cretaceous flora, p. 51, pl. 1, figs. 10-10b, 1874; The flora of the Dakota group, p. 35, pl. 2, fig. 4, 1892.

Engelhardt, Naturwiss. Gesell. Isis in Dresden Abh. 7, Jahrg. 1891, p. 91, 1892.

Hollick, New York Acad. Sci. Trans., vol. 12, p. 30, pl. 1, fig. 18, 1892; The Cretaceous flora of southern New York and New England, p. 42, pl. 2, fig. 40; pl. 3, figs. 4, 5, 1907.

Newberry, The flora of the Amboy clays, p. 49, pl. 9, fig. 19, 1896.

Berry, New York Bot. Garden Bull., vol. 3, p. 59, pl. 48, figs. 15-18, 20, 1903; Torrey Bot. Club. Bull., vol. 31, p. 69, pl. 4, fig. 8, 1904; idem, vol. 32, p. 44, pl. 1, fig. 3, 1905; idem, vol. 33, p. 165, 1906; New Jersey Geol. Survey Bull. 3, p. 93, 1911; Maryland Geol. Survey, Lower Cretaceous, p. 444, pl. 77, fig. 7, 1911.

Knowlton, Smithsonian Misc. Coll., vol. 4, pt. 1, p. 126, pl. 12, figs. 7, 8, 1907; U. S. Geol. Survey Mon. 32, p. 657, 1899; U. S. Geol. Survey Bull. 257, p. 131, pl. 14, figs. 3-5, 1905.

Araucaria reichenbachi (Geinitz) Heer. Debey, Entwurf geognostisch-geogenetischen Darstellung den Gegend von Aachen, Nachtrage, 1849.

Sequoia reichenbachi longifolia Fontaine, The Potomac or younger Mesozoic flora, p. 244, pl. 117, fig. 8, 1889.

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[1] Berry, E. W., Torrey Bot. Club Bull., vol. 31, p. 68, pl. 1, fig. 12, 1904.

[2] Only representative citations, chiefly American, of this widespread and persistent species are given.

Sequoia densifolia Fontaine, The Potomac or younger Mesozoic flora, p. 246, pl. 121, fig. 4, 1889.

Sequoia? sp. Fontaine, The Potomac or younger Mesozoic flora, p. 248, pl. 116, fig. 7; pl. 132, figs. 2, 5, 6, 1889.

Sequoia sp. Fontaine, The Potomac or younger Mesozoic flora, p. 248, pl. 132, fig. 10, 1889.

Sequoia? inferna Ward. Fontaine, in Ward, Status of the Mesozoic floras of the United States, p. 507, 1905.

Sequoia couttsiae Heer. Hollick, New York Acad. Sci. Trans., vol. 12, p. 30, pl. 1, fig. 5, 1892.

This species has a recorded range on this continent from the supposed Neocomian of Mexico to the Livingston formation of Montana, being very abundant at numerous horizons, and it has likewise been identified from Greenland and Europe. The view has frequently been voiced that some at least of these identifications are erroneous, which is probable enough, although the Tertiary *Sequoia langsdorfii* has an almost equally wide range, both geologic and geographic. In a memoir recently published, Hollick and Jeffrey[1] present their studies of the anatomy of some twigs of the *Sequoia reichenbachi* type from the upper part of the Raritan formation of Staten Island. According to these authors their results indicate that these remains are referable to the genus *Geinitzia* and are araucarian in their affinity, a view which has been tentatively suggested by numerous students since the days of Geinitz, who referred them to the genus *Araucarites*. In order to make out a good case Hollick and Jeffrey are under the necessity of finding araucarian characters in certain associated cone scales of the *Sequoia* type, as these supposed araucarian twigs frequently are found with *Sequoia*-like cones attached to them. This they do, referring these cone scales to new genera which they term *Eugeinitzia* and *Pseudogeinitzia*, although the evidence for an araucarian affinity is extremely slender.

As might be expected from their great range, fossils of the *Sequoia reichenbachi* type are of slight stratigraphic value; nevertheless the remains are very abundant from New Jersey to Alabama at the Magothy, Black Creek (including Middendorf), Tuscaloosa, and Eutaw horizon, apparently identical in character and commonly cone bearing, the cones being small, a prolate spheroid in shape, and consisting of relatively few, peltate, umbilicate, *Sequoia*-like scales. *Sequoia* twigs are very resistant to maceration, and commonly are about the last vegetable remains to disintegrate in marine waters.

This species is rare in the Raritan formation but common at later Upper Cretaceous outcrops in New Jersey, Delaware, Maryland, North Carolina, South Carolina, Georgia, and Alabama. In Alabama it has been found from the lower third of the Tuscaloosa formation upward through the Eutaw formation. It is not commonly represented in the earliest Tuscaloosa sediments, where it appears to be replaced by *Sequoia ambigua* Heer and species of *Widdringtonites*. How far its absence represents merely accidents of preservation can not be determined. Material that may represent this species but in a much macerated and not positively determinable condition occurs near the base of the Tuscaloosa formation near Cottondale, in Tuscaloosa County, Ala. Toward the top of the Tuscaloosa and in the basal part of the Eutaw formation it is very common.

Occurrence: Tuscaloosa formation, big gully on the Snow place and upper beds at Cottondale (?), Tuscaloosa County; Whites Bluff, Greene County, Ala. Cut on Southern Railway, 1⅝ miles east of Iuka, Tishomingo County, Miss. (common). Eutaw formation (basal part), 2 miles south of Havana, Hale County, Ala.; McBrides Ford, Chimney Bluff; Broken Arrow Bend, Chattahoochee County, Ga.

Collections: U. S. National Museum.

Sequoia heterophylla Velenovsky.

Sequoia heterophylla Velenovsky, Die Gymnospermen der böhmischen Kreideformation, p. 22, pl. 12, fig. 12; pl. 13, figs. 2–4, 6–9, 1885; K. böhm. Gesell. Wiss. Sitzungsber., 1888, p. 593, figs. 7, 8. (Not Smith, E. A., On the geology of the Coastal Plain of Alabama, p. 348, 1894.)

Engelhardt, Naturwiss. Gesell. Isis in Dresden Abh. 7, Jahrg. 1891, p. 104, 1892 (?).

Hollick, New York Acad. Sci. Trans., vol. 12, p. 3, pl. 1, fig. 18, 1892; The Cretaceous flora of southern New York and New England, p. 41, pl. 3, figs. 2, 3, 1906.

Ward, U. S. Geol. Survey Fifteenth Ann. Rept., pp. 378, 380, 382, 392, 1895.

Newberry, The flora of the Amboy clays, p. 49, pl. 6, figs. 1–13, 1896.

Knowlton, U. S. Geol. Survey Bull. 257, p. 132, pl. 16, fig. 5, 1905.

Berry, Torrey Bot. Club Bull., vol. 33, p. 165, 1906; idem, vol. 34, p. 189, 1907; New Jersey Geol. Survey Ann. Rept. for 1905, p. 139, 1906; New Jersey Geol. Survey Bull. 3, p. 95, pl. 6, 1911.

This characteristic species, described originally from the Cenomanian and Emscherian of

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[1] Hollick, Arthur, and Jeffrey, E. C., New York Bot. Garden Mem., vol. 3, p. 38, pl. 5, 1909.

Bohemia, may be readily recognized by the form of the foliage—the flat, lanceolate, decurrent leaves above, and the short and appressed leaves below. Newberry says of this species that it is "one of the most common conifers of the Amboy clays," but he mentioned no localities. I have found it only in the upper part of the Raritan formation at South Amboy, N. J., where it is very common, and at a still higher horizon in the Raritan, at the Hylton Pits, and it has been collected by Hollick from a probably equivalent horizon at Kreischerville, Staten Island.

In the overlying Magothy formation it is a common species, and its recorded range extends from Marthas Vineyard to Maryland. It also occurs in the allied Black Creek formation of North Carolina. In the West it is said to occur in the Judith River formation of Montana.

In 1888 Velenovsky described additional twigs of this species and cones from the Cenomanian of Hloubětín, Bohemia, although he does not state that they were attached. The cones were of small size, 2.3 by 1.5 centimeters, elliptical in outline, and were made up of a relatively small number of slender, rhomboidal, umbilicate scales of the *Sequoia* type.

In the Alabama area *Sequoia heterophylla* was identified by Ward in collections from the Snow place, Tuscaloosa County, and recorded from there by Smith in 1894.[1] This determination was erroneous, however, as the material lacks the dimorphism of this species, and in its venation shows that it is identical with *Dicksonia groenlandica* Heer. Typical specimens of *Sequoia heterophylla* have been collected by the writer, however, from the Tuscaloosa formation.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; Whites Bluff, Greene County, Ala.

Collections: U. S. National Museum.

Sequoia ambigua Heer.

Plate VI, figures 3, 4.

Sequoia ambigua Heer, Flora fossilis arctica, vol. 3, pt. 2, pp. 78, 91, pl. 21, figs. 1-11; pl. 25, fig. 5, 1874; vol. 6, pt. 2, pp. 17, 52, pl. 1, fig. 3, 1882.

Fontaine, The Potomac or younger Mesozoic flora, p. 245, pl. 118, fig. 2; pl. 120, figs. 1-6; pl. 127, fig. 5; pl. 132, fig. 3, 1889.

Nathorst, in Felix and Lenk, Beiträge zur Geologie und Paleontologie der Republik Mexico, p. 51, figs. 1-3, 1893.

Fontaine, in Ward, Status of the Mesozoic floras of the United States, pp. 272, 281, 538, pl. 69, fig. 6; pl. 110, fig. 13, 1905.

Berry, Maryland Geol. Survey, Lower Cretaceous, p. 449, pl. 78, figs. 1-7, 1911.

Sphenolepidium recurvifolium Fontaine, The Potomac or younger Mesozoic flora, p. 258, pl. 128, figs. 2-6; pl. 129, fig. 5; pl. 130, figs. 4-6, 10, 1889.

Fontaine, in Ward, Status of the Mesozoic floras of the United States, pp. 484, 528, 538, 546, 555, 1905.

Sequoia gracilis Fontaine, in Ward, U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, p. 675, pl. 166, fig. 2, 1899.

Arthrotaxopsis expansa Fontaine, in Ward, Status of the Mesozoic floras of the United States, pp. 533, 535, 538, 555, 573, pl. 109, figs. 12, 13 (not pp. 504, 520, 547, 571), 1905.

Remains of the foliage of this species are distinguishable from those of contemporaneous conifers, which occur in the beds with them, by the relatively short and very stout, acuminate, falcate, or recurved, decurrent leaves.

The cones are spherical and consist of relatively few, short scales with longitudinally striated peduncles and suddenly expanded, quadrangular, peltate, umbilicate tips. These cones are abundant in the Lower Cretaceous of Maryland, occurring usually as detached ferruginized mud casts, and are fully described by the writer elsewhere.[2]

As recorded in the literature cited above, *Sequoia ambigua* is widely distributed geographically, and it has an equally great geologic range. It was described originally from the Kome beds (Barremian) of Greenland by Heer, and this author soon afterward recorded it from the Upper Cretaceous Atane beds of that country. It has been recorded by Nathorst from the supposed Neocomian of Mexico and it is present in the Kootenai formation of Montana. It is a member of the Shasta flora of the Pacific coast (Horsetown formation) and is probably represented in the Fuson shale of eastern Wyoming by what Fontaine calls *Sequoia gracilis*. In the Upper Cretaceous, remains in every way identical with these Lower Cretaceous occurrences are present in the Magothy formation at Gay Head, Marthas Vineyard, and at a number of localities in Maryland, as well as in the Tuscaloosa formation of Alabama. After much comparison and study the writer is unable to formulate good characters for the separation of the later from the earlier Cretaceous forms of this species.

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[1] Smith, E. A., On the geology of the Coastal Plain of Alabama, p. 348, Alabama Geol. Survey, 1894.

[2] Berry, E. W., Maryland Geol. Survey, Lower Cretaceous, p. 449, pl. 78, figs. 1-7, 1911.

The Upper Cretaceous forms resemble greatly some of the homotaxial remains referred by Heer and others to *Sequoia subulata* Heer and to *Sequoia fastigiata* (Sternberg) Heer. They are, however, different from the types of both of these species, and it seems probable that the later identifications include diverse species under these names. The fragments figured in 1876 by Lesquereux from the Dakota sandstone as *S. fastigiata* are also quite similar to the Alabama specimens. The species has recently been fully discussed and illustrated by the writer.[1]

Occurrence: Tuscaloosa formation, upper ravine and foot of big gully on the Snow place, Tuscaloosa County, Ala. (common). Eutaw formation, 2 miles south of Havana, Hale County, Ala.

Collections: U. S. National Museum.

Sequoia fastigiaa (Sternberg) Heer.

Caulerpites fastigiatus Sternberg, Versuch einer geognostisch-botanischen Darstellung der Flora der Vorwelt, vol. 2, p. 23, 1833.

Sequoia fastigiata (Sternberg) Heer, Flora von Moletein in Mähren, p. 11, pl. 1, figs. 10–13, 1869; Flora fossilis arctica, vol. 3, pt. 2, pp. 102, 128, pl. 27, figs. 5, 6; pl. 38, figs. 12, 13, 1874; idem, vol. 6, pt. 2, p. 53, pl. 3, figs. 7–9; pl. 17, fig. 4; pl. 28, fig. 6, 1882; idem, vol. 7, p. 15, pl. 51, figs. 11, 12; pl. 53, figs. 3, 4, 1883.

Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 391 (1875), 1876; U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, p. 335, pl. 3, figs. 2, 8, 1876; The Cretaceous and Tertiary floras, p. 31, 1883.

Velenovsky, Die Gymnospermen der böhmischen Kreideformation, p. 21, pl. 8, fig. 13; pl. 9, figs. 3, 4, 9, 10; pl. 11, figs. 1, 2; pl. 12, fig. 13, 1885.

Hollick, The Cretaceous flora of southern New York and New England, p. 43, pl. 3, fig. 15, 1906.

Thuites alienus Sternberg, idem, vol. 1, pl. 45, fig. 1, 1833.

Widdringtonites fastigiatus (Sternberg) Endlicher, Synopsis coniferarum, p. 272, 1847.

Goeppert, Monographie der fossilen Coniferen, p. 176, 1850.

Unger, Genera et species plantarum fossilium, p. 342, 1850.

Remains that are supposed to represent this species are recorded from the Cenomanian of Moravia and Bohemia, the Cretaceous of Greenland and Spitzbergen, the Dakota sandstone of Kansas, and the Magothy formation on Marthas Vineyard. The students who have described this form may possibly have confused it with *Sequoia gracilis* Heer and *Sequoia concinna* Heer, as well as with other supposed species of *Sequoia* and *Widdringtonites*. A revision of all of these similar if not in part identical forms would be desirable but should not be attempted without abundant and representative material from the different countries. Specimens identical with what has been called *Sequoia fastigiata* occur in the lower part of the Tuscaloosa formation, where they are associated with forms of similar appearance but of larger size, which are referred to *Sequoia ambigua* Heer, and with smaller forms shown by their cones to be *Widdringtonites subtilis* Heer. I doubt very much the specific integrity of *Sequoia fastigiata*, but until the whole question can be revised unnecessary changes are undesirable. Similar foliar remains from the Bingen formation in Arkansas have been referred to *Sequoia concinna* Heer because of the associated cones.[2]

Occurrence: Tuscaloosa formation, big gully on the Snow place, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Genus WIDDRINGTONITES Endlicher.

[Synopsis coniferarum, p. 271, 1847.]

Widdringtonites subtilis Heer.

Plate VIII, figures 1–12.

Widdringtonites subtilis Heer, Flora fossilis arctica, vol. 3, Abt. 2, p. 101, pl. 28, fig. 1b, 1874; idem, vol. 6, Abt. 2, pl. 7, figs, 14, 15; pl. 28, fig. 4b, 1882.

Newberry, The flora of the Amboy clays, p. 57, pl. 10, figs. 2–4, 1896.

Hollick, The Cretaceous flora of southern New York and New England, p. 45, pl. 4, figs, 2–5, 1906.

Berry, New Jersey Geol. Survey Bull. 3, p. 89, 1911; Torrey Bot. Club Bull., vol. 39, pp. 341–348, pls. 24, 25, 1912.

Widdringtonites reichii (Ettingshausen) Heer. Hollick, New York Acad. Sci. Ann., vol. 11, p. 58, pl. 3, fig. 8, 1898.

Berry, Johns Hopkins Univ. Circ., new ser., No. 7, p. 81, 1907.

This species was described from the Atane beds of Greenland by Heer in 1874. His material was, however, extremely scanty. Subsequently it was found in considerable abundance in the Raritan formation of New Jersey, and still more recently Hollick has recorded it from Marthas Vineyard and Block Island (Magothy formation). I have found it in the Magothy formation of Maryland and the Middendorf arkose member of the Black Creek formation of South Carolina. Possibly also some of the coniferous material described by Velenovsky from the Bohemian Cretaceous under other names should be compared with the present form.

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[1] Berry, E. W., Maryland Geol. Survey, Lower Cretaceous, p. 449, pl. 78, figs. 1–7, 1911.

[2] Berry, E. W., Torrey Bot. Club Bull., vol. 43, p. 172, pl. 7, figs. 1–5, 1917.

The material from the Tuscaloosa formation is abundant, especially so at the locality known as the Snow place, and enables us to make a considerable addition to the knowledge of this species, which may be described as follows: Twigs slender, relatively short, somewhat lax in habit. Foliage somewhat dimorphic, at least the leaves on the young shoots are quite different in appearance from those on the older twigs. Young leaves short, thick, and directed distad, ovate, and appearing bluntly rounded apically because of the inwardly directed pointed tip, 0.5 to 1 millimeter in length, having the appearance of a cyclic phyllotaxy but really arranged spirally. With age the leaves become elongated basally and somewhat spreading, at times falcate. The old leaves are two or three times as long as the young leaves, and as they are about the same thickness they are relatively much more slender and needle-like. The twig enlarged in Plate VIII shows the two kinds of leaves. The degree of spreading or appression differs in different specimens, owing probably in some measure to the conditions attending fossilization. A form with uniformly slender and spreading leaves is common at Shirleys Mill, a twig of which is shown in figure 5. In his discussion of this species Newberry mentions a vague cone about 1 centimeter in diameter as included in the Raritan material. I have not seen this specimen, but I have found a number of poorly preserved detached cones among the abundant remains of this species in the Upper Cretaceous beds of South Carolina. A number of specimens from the Tuscaloosa formation have these cones attached to the characteristic twigs of this species. These cones are terminal, roughly spheroidal in outline, and apparently consist of four thick, subequal scales with wide blunt tips and somewhat extended bases. They are 7 centimeters to 9 millimeters in length and 4 or 5 millimeters in diameter, and are closely comparable to the cones from the Upper Cretaceous of eastern Europe ascribed to *Widdringtonites reichii* by both Velenovsky and Krasser. These authors refer this form directly to the genus *Widdringtonia*, and it would seem that the cones attached to the Alabama specimens of *Widdringtonites subtilis* conclusively demonstrate the relationship between a number of these Mesozoic conifers and the existing species of *Callitris*, *Widdringtonia*, and *Frenela*, which Eichler lumps into the single genus *Callitris* Ventenat.

At the present time they constitute a small group confined to the Australian region on the one hand (*Frenela*) and to northern Africa (*Eucallitris*) and southern Africa and Madagascar (*Widdringtonia*) on the other. In former geologic periods they were much more abundant. *Frenelopsis* is recorded in America from Greenland to Texas, and *Widdringtonites* from Greenland to Alabama. Abroad both types occur abundantly in central and western Europe. Like so many other types of plants which were widespread in Mesozoic time, they became more and more restricted in their range during the Tertiary until to-day they are not found at all in the Western Hemisphere. As regards Cretaceous species of *Widdringtonites*, 4 occur in the Neocomian, 1 in the Barremian, 1 in the Albian, 3 in the Cenomanian, and 1 in the Senonian.

The present species has much shorter twigs than the Upper Cretaceous species, *Widdringtonites reichii* (Ettingshausen) Heer, or the late Lower Cretaceous species, *Widdringtonites ramosus* (Fontaine) Barry.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; upper ravine and foot of big gully on the Snow place, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Widdringtonites reichii (Ettingshausen) Heer.

Frenelites reichii Ettingshausen, Die Kreideflora von Niederschoena in Sachsen, p. 12, pl. 1, figs. 10a-c, 1867.
Hollick, New York Acad. Sci. Trans., vol. 12, p. 29, pl. 1, fig. 23, 1892.
Widdringtonites reichii (Ettingshausen) Heer, Flora fossilis arctica, vol. 6, pt. 2, p. 51, pl. 28, fig. 5, 1882; idem, vol. 7, p. 13, pl. 52, figs. 4, 5, 1883.
Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.
Newberry, The flora of the Amboy clays, p. 57, pl. 8, figs. 1-5, 1896.
Berry, Torrey Bot. Club Bull., vol. 33, p. 169, 1906; New Jersey Geol. Survey Ann. Rept. for 1905, p. 138, 1906; New Jersey Geol. Survey Bull. 3, p. 87, pl. 8, figs. 1, 2, 1911.
Hollick, The Cretaceous flora of southern New York and New England, p. 44, pl. 4, figs. 6-8, 1906.
Widdringtonia reichii (Ettingshausen) Velenovsky, Die Gymnospermen der böhmischen Kreideformation, p. 27, pl. 8. figs. 4-6; pl. 10, figs. 1, 11, 12, 1885; K. böhm. Gesell. Wiss. Sitzungsber., 1886, p. 639 (6), pl. 1, figs. 14-16, 1887.
Engelhardt, Naturwiss. Gesell. Isis in Dresden Abh. 7, Jahrg. 1891, p. 92, 1892.
Marik, Prispevek, k. fl. českého cenomanu, p. 9, pl. 1, fig. 23; pl. 2, fig. 2, 1901.
Krasser, Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, Band 10, p. 126 (14), pl. 14 (4), fig. 6; pl. 17 (7), figs. 4, 7, 8, 1896.
Glyptostrobus gracillimus Lesquereux, Am. Jour. Sci., 2d ser., vol. 46, p. 92, 1868; The Cretaceous flora, p. 52, pl. 1, figs. 8, 11-11f, 1874; The Cretaceous and Tertiary floras, p. 32, pl. 1, figs. 6-6b, 1883; The flora of the Dakota group, p. 38, 1892.
Sequoia gracillima (Lesquereux) Newberry, The flora of the Amboy clays, p. 50 (in part), (not pl. 9, figs. 1-3, 1896); The later extinct floras of North America, p. 19 (in part), pl. 14, fig. 6, 1898 (not pl. 26, fig. 9).
Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.

Ettingshausen's description, published in 1867, is as follows:

> F. ramis suberectis fastigiatis, ramulis filiformibus confertis, foliis adpressis e basi ovata subulatis, strobilis axillaribus duplo longioribus quam latis.

Medium-sized branches with more or less crowded, slender, elongated, fastigiate twigs, bearing reduced ovate-subulate leaves, spirally arranged. The cones are small oval bodies, 5 to 12 millimeters long by 3 to 7 millimeters in diameter, usually poorly preserved, said by Ettingshausen to be axillary in position but evidently many of them terminal, as evinced by some of the Raritan material as well as by some of the better-preserved cones from the Cenomanian of Bohemia and Moravia. The Bohemian and Moravian material clearly shows that the cones consisted of four scales. This feature would ally it with either the subgenus *Widdringtonia* of the genus *Callitris* Ventenat, to which Eichler, in his treatment of the living species in Engler and Prantl (1887) refers Endlicher's genus, or to the subgenus *Eucallitris* Brongniart, which also is characterized by four cone scales. *Eucallitris* has a single living species of northern Africa, and *Widdringtonia* has three or four species of southern Africa and Madagascar. The propriety of Eichler's classification may well be questioned, and in any event paleobotanists must necessarily prefer the older segregation of *Frenela* and *Widdringtonia* and their respective form genera.

There seems to be but little doubt that the present species should be referred to *Widdringtonia*, as Velenovsky and Krasser have done, but as the term *Widdringtonites* is equally indicative of its true affinity, little is to be gained by making the proposed change.

The species was described originally by Ettingshausen from the Cenomanian of Niederschoena in Saxony as a species of *Frenelites.* When Heer discovered it in the Greenland material, where it has been collected from both the Atane and the Patoot beds, he transferred it to the present genus. It has subsequently been reported from the Cenomanian of Bohemia and Moravia, from the Magothy formation of the Atlantic Coastal Plain at numerous localities, and from the islands of southern New England. It is also present in North Carolina and South Carolina. Heer made *Glyptostrobus gracillimus* Lesquereux, of the Dakota sandstone, a synonym of this species, and this form, under the name *Sequoia gracillima* Newberry, has been identified from a large number of localities, including the Dakota sandstone of the West.

Widdringtonites reichii is closely allied to if not identical with a common conifer of the Patapsco formation (Albian) of Maryland and Virginia, which the writer has described as *Widdringtonites ramosus.*[1] This species is based upon *Taxodium ramosum* and other so-called species described by Fontaine from the Potomac group.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, Fayette County; Whites Bluff, Greene County; big gully and upper ravine on the Snow place, Tuscaloosa County, Ala.

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[1] Berry, Maryland Geol. Survey, Lower Cretaceous, p. 428, pl. 73, figs. 1-6, 1911.

Collections: U. S. National Museum.

Genus PINUS Linné.

[Species plantarum, p. 1000, 1753.]

Pinus raritanensis Berry.

Pinus raritanensis Berry, Torrey Bot. Club Bull., vol. 36, p. 247, 1909. New Jersey Geol. Survey Bull. 3, p. 92, 1911.

Pinus sp., Newberry, The flora of the Amboy clays, p. 47, pl. 9, figs. 5, 6; figs. 7, 8 (?), figs. 17, 18 (?), 1896.

This species was discovered in the upper part of the Raritan formation of South Amboy, N. J. The remains consist of slender leaves in fascicles of threes and poorly preserved winged seeds. Similar remains occur in the Magothy formation of New Jersey, in the Black Creek formation of North Carolina, and in the Middendorf arkose member of the Black Creek formation of South Carolina. They are too indefinite to have much stratigraphic value, and they are of slight botanic interest beyond showing the presence of a pinelike form in the Upper Cretaceous of the Atlantic coast. In this connection attention should be called to structural material of *Pinus*, described by Hollick and Jeffrey,[1] from the Raritan formation on Staten Island, N. Y., as *Pinus triphylla*, which may be identical with the present form.

Pinus-like leaves are recorded from the Kome beds of Greenland, the Kootenai formation of the West, the Trinity group of Texas, the Lakota sandstone of the Wyoming-South Dakota region, and the Patapsco formation of Maryland, and the Albian of Europe is remarkable for the large number of *Pinus*-like cones which it contains. Heer has also recorded five species from the Atane beds of western Greenland.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Genus TUMION Rafinesque.

Tumion carolinianum Berry (?).

Tumion carolinianum Berry, Am. Jour. Sci., 4th ser., vol. 25, p. 383, figs. 1-3, 1908; U. S. Geol. Survey Prof. Paper 84, p. 107, 1914.

This species has recently been described by me in the publications cited.

Occurrence: Eutaw formation, McBrides Ford, Chattahoochee County, Ga.

Collection: U. S. National Museum.

Genus CUPRESSINOXYLON Goeppert.

Cupressinoxylon sp.

Silicified wood is not uncommon in the Coffee sand of western Tennessee. Sections were cut of fragments broken from large logs preserved in these sands at Coffee Bluff. The material had evidently undergone considerable decay before silicification and the essential features for specific diagnosis are obscure, so that it has seemed best not to attempt a description until better preserved material becomes available.

Occurrence: Eutaw formation (Coffee sand member), Coffee Bluff, Hardin County, Tenn.

Collection: Johns Hopkins University.

Class ANGIOSPERMAE.

Subclass MONOCOTYLEDONAE.

Order LILIALES.

Genus DORYANTHITES Berry.

Doryanthites cretacea Berry.

Plate XIII, figure 1.

Doryanthites cretacea Berry, Torrey Bot. Club Bull., vol. 38, p. 406, 1911.

Leaves, as preserved, linear, presumably lanceolate above and sheathing below, 4.5 to 6 centimeters in width and preserved without any diminution in width for a length of 50 centimeters. Texture very coriaceous. Margins entire. Veins simple and parallel, immersed, considerably less than 1 millimeter apart. Leaves alike on both surfaces. In the hollows between the veins occur rows of small stomata with the guard cells all oriented in a direction parallel with the veins and equally numerous on both surfaces of the leaf. Leaf surface under the microscope appearing finely striated parallel with the veins.

These curious remains, which call to mind the leaves of the Paleozoic *Cordaites* or some modern giant bromeliad, are not uncommon in the Upper Cretaceous. They were first discovered by the writer in the Black Creek formation of North Carolina, and it is from this material that the stomatal characters are described. Recently this same form was discovered in considerable abundance at the Georgia locality near Buena Vista, Marion

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[1] Hollick, Arthur, and Jeffrey, E. C., New York Bot. Garden Mem., vol. 3, p. 14, pl. 3, figs. 6, 7 (?); pl 22, fig. 1, 1909.

County, and in the Magothy formation of Maryland.

With regard to similar remains previously described, it may be noted that Miquel[1] in 1853 described under the heading "Phyllitae monocotylei" two sorts of parallel-veined leaf fragments from the Upper Cretaceous of Aachen (Rhenish Prussia). The first[2] he calls *Yuccites?*, and the second, which suggests the fossils under discussion, is designated "*Palma* vel *Yuccites?*." From the Valanginian of Portugal, Heer[3] described what he calls *Bambusium latifolium*, which is also suggestive of the American material. Krasser[4] describes somewhat similarly appearing remains from the Cretaceous (Cenomanian?) of Moravia as *Typhaeloipum cretaceum*. These are somewhat smaller than the American forms and show transverse veinlets which are absent in the latter. Smaller but otherwise comparable Lower and Upper Cretaceous forms were named by Schenk *Eolirion*,[5] and similar older Mesozoic forms are commonly referred to the form genus *Yuccites*.[6] Perhaps the most similar fossils known are those referred to the genus *Krannera*[7] and fully described by Velenovsky, who does not, however, arrive at any satisfactory conclusion regarding their relationship, although he thinks they are cycadaceous.

It seems undesirable to refer the present material to *Yuccites*, for though it is similar in appearance to the more ancient remains so named, it is entirely improbable that it is congeneric with the Triassic type upon which this genus was founded, and such an identification would consequently be very misleading. Until the existing tropical Monocotyledonae are more abundantly represented in our larger herbaria, or more complete and decisive Cretaceous material is discovered, the botanic affinity of these anomalous forms must remain undetermined. The name chosen indicates superficial resemblance and does not imply any close relationship with the modern genus *Doryanthes* of the order Liliales.

Little reliance can be placed upon similarity of appearance in dealing with fragmentary remains of this sort, and the foregoing are mentioned merely as indicating the presence of undetermined monocotyledons of large size in the Cretaceous floras of the world.

Occurrence: Eutaw formation (basal part), 2 miles south of Havana, Hale County, Ala. Ripley formation (Cusseta sand member), Buena Vista, Marion County, Ga.

Collections: U. S. National Museum.

Order GRAMINALES.

Genus CYPERACITES Schimper.

Cyperacites sp. Hollick.

Cyperacites sp., Hollick, The Cretaceous flora of southern New York and New England, p. 48, pl. 6, figs. 7, 8, 1906.

Cyperites? Hollick, Torrey Bot. Club Bull., vol. 21, p. 63, pl. 180, fig. 3, 1894.

Grass or sedgelike remains indistinguishable from the above form, described by Hollick from the Magothy formation of Glen Cove, Long Island, are present in the Tuscaloosa flora. They are also practically indistinguishable from similar remains described by Heer from West Greenland and by other authors from different horizons. None of the specimens present real specific characters and they have little value or interest. The present remains greatly resemble those of *Podozamites marginatus* Heer, which is so abundant at near-by localities, but may be distinguished by their greater elongation and the possession of a well-marked midrib.

Occurrence: Tuscaloosa formation, roadside southwest of Northport, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Genus PHRAGMITES Trinius.

Phragmites prattii Berry.

Phragmites prattii Berry, idem, vol. 37, p. 191, 1910; U. S. Geol. Survey, Prof. Paper, p. 28, 1914; Bull. Torrey Bot. Club, vol. 43, p. 287, 1916.

Phragmites sp. Berry, Torrey Bot. Club Bull., vol. 34, p. 190, pl. 11, fig. 5, 1907.

I have described this form in the papers cited and the description need not be repeated here.

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[1] Miquel, F. A. W., De fossiele planten van het Krijt in het Hertogdom Limburg, Comm. Geol. kaart. Nederland Verh., vol. 1, pp. 33-56, pl. 1-7, 1853.

[2] Idem, pl. 1, fig. 3.

[3] Heer, Oswald, Contributions à la flore fossile du Portugal, p. 22, pl. 19, figs. 1-3, 1881.

[4] Krasser, F. von, Beiträge zur Kenntniss der fossilen Kreideflora von Kunstadt, p. 15, pl. 2, fig. 4, 1896.

[5] Schenk, August, Palaeontographica, vol. 19, p. 20, 1869.

[6] Schimper, W. P., and Mougeot, A., Monographie des plantes fossiles du grès bigarré de la chaine des Vosges, p. 42, 1844.

[7] Velenovsky, Josef, Die Gymnospermen der böhmsichen Kreideformation, p. 1, 1885.

Occurrence: Eutaw formation, Broken Arrow Bend, Chattahoochee County, Ga.; (Coffee sand member), Coffee Bluff, Hardin County, Tenn.

Collections: U. S. National Museum.

Order ARECALES.

Genus SABALITES Saporta.

Sabalites sp.

Plate XI, figure 1.

Fragments of leaves of a large fan palm are present in the basal Ripley formation of Benton and McNairy counties, Tenn. They indicate large flabellate leaves, with numerous rays 1.5 to 2 centimeters broad having an illy defined midrib and close-set parallel lateral veins. The texture is coriaceous.

The material is very fragmentary, one of the best specimens being that figured, which is altogether insufficient for specific diagnosis. It is in my judgment distinct from the so-called *Sabalites grayanus* Lesquereux of the Montana group of the West, *Sabalites magothiensis* Berry of the Magothy formation of the northern Atlantic coast, or *Sabalites carolinensis* Berry of the Middendorf arkose member of the Black Creek formation of South Carolina.

Occurrence: Ripley formation (McNairy sand member), half a mile from Camden, Benton County (collected by L. W. Stephenson); 2½ miles southwest of Selmer, McNairy County, Tenn. (collected by Bruce Wade).

Collections: U. S. National Museum.

Subclass DICOTYLEDONAE.

Order PIPERALES.

Family PIPERACEAE.

Genus PIPERITES Goeppert.

[Die Tertiärflora auf der Insel Java, p. 40, 1854.]

Piperites tuscaloosensis Berry, n. sp.

Plate XII, figure 3.

Leaves alternate on a flexuous twig, ovate-lanceolate in outline, inequilateral, about 6 to 7 centimeters in length by 3 centimeters in maximum width,[1] which is in the basal half of the leaf. Apex narrowed and acute. Base more or less inequilateral, at first broadly rounded and then slightly decurrent on the upper side, narrow and incurved on the lower side. Petiole mediumly stout, about 1.5 centimeters in length or slightly less. Midrib stout, usually curved. Secondaries stout, few in number, the basal pair subopposite, branching from the midrib near its base at an acute angle, longer and stouter than succeeding pairs, giving the leaves a decidedly triveined character. Margins entire, very slightly repand.

The present species is entirely unlike any previously known Upper Cretaceous plant, although the inequilateral leaves suggest at first sight the forms described from beds of similar age as different species of Phaseolites, as for example *Phaseolites formus* Lesquereux [2] from the Dakota sandstone and *Phaseolites elegans* [3] and *Phaseolites manhassettensis* Hollick [4] from the Raritan formation of Long Island and New Jersey. It is not impossible that Hollick's species may represent leaves of Cretaceous forms allied to the modern genus *Piper* instead of being the detached leaflets of Cretaceous species allied to the modern genus *Phaseolus* with trifoliate leaves. This last possibility certainly is not indicated for the Alabama material, which shows an unmistakable likeness to many of the numerous existing species of the genus *Piper*. The representatives of that genus are numerous in the warmer parts of both hemispheres, the various species combining a form like that of a fossil with a venation ranging from pinnate secondaries to subpalmate and palmate species.

Forms referable to the present family have been rarely recognized in fossil floras, except for the unmistakable forms described from the Tertiary of the East Indies by Heer and Goeppert.[5] Ettingshausen described a species [6] from the Tertiary of Australia and Lesquereux one [7] from the Denver formation at Golden, Colo., but I have not seen any of these forms.

Occurrence: Tuscaloosa formation, grounds of the State University, Tuscaloosa, Tuscaloosa County; Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

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[1] All measurements of leaves in this report are of the blades. The lengths given are exclusive of the petiole, which when preserved is given separately.

[2] Lesquereux, Leo, Flora of the Dakota group, p. 147, pl. 55, figs. 5, 6, 12, 1892.

[3] Hollick, Arthur, U. S. Geol. Survey Mon. 50, p. 85, pl. 32, fig. 4, 1907.

[4] Hollick, Arthur, New York Bot. Garden Bull., vol. 3, p. 414, pl. 78, figs. 1, 2, 1904.

[5] *Piperites bullatus* Göppert, *P. hasskarlianus* Göppert, and *P. miquelianus* Göppert, from Java, and *Piper antiquum* Heer, from Sumatra.

[6] *Piper feistmantelii* Ettingshausen, Beiträge zur Kenntniss der Tertiärflora Australiens, pt. 2, p. 16, pl. 9, fig. 4, 1886.

[7] *Piper heerii* Lesquereux, Harvard Coll. Mus. Comp. Zool Bull., vol. 16, p. 44, 1888.

Order JUGLANDALES.

Family JUGLANDACEAE.

Genus JUGLANS Linné.

Juglans arctica Heer.

Juglans arctica Heer, Flora fossilis arctica, vol. 6, pt. 2, p. 71, pl. 40, fig. 2; pl. 41, fig. 40; pl. 42, figs. 1-3; pl. 43, fig. 3, 1882.

Lesquereux, The flora of the Dakota group, p. 68, pl. 19, fig. 3, pl. 39, fig. 5, 1892.

Newberry, The flora of the Amboy clays, p. 62, pl. 20, fig. 2, 1896. Hollick, Ann. Acad. Sci. New York, vol. 11, p. 58, pl. 3, fig. 7, 1898. Berry, New Jersey Geol. Survey Ann. Rept. for 1905, p. 139, pl. 21, fig. 1, 1906; Torrey Bot. Club Bull., vol. 33, p. 170, 1906; New Jersey Geol. Survey Bull. 3, p. 110, 1911.

Hollick, The Cretaceous flora of southern New York and New England, p. 54, pl. 9, figs. 6-8, 1906.

Ficus atavina Heer. Hollick, New York Acad. Sci. Trans., vol. 11, p. 103, pl. 4, fig. 5, 1892.

The leaves of this species differ considerably in size and outline, as might be expected in the present genus. Heer's type material is somewhat imperfect, and some of it can with difficulty be discriminated from some of the forms referred to the same author's *Juglans crassipes*, although that species is on the whole a much larger form with a narrower base and is less oblong in outline. *Juglans arctica* is oblong-ovate in outline with an obtusely pointed apex, and a rounded, generally inequilateral base. The petiole and midrib are stout. Secondaries numerous, well marked, parallel, camptodrome. The size ranges in complete specimens from 9 to 15 centimeters in length and from 3 to 6 centimeters in width.

A nut and catkins are associated with the leaves at the type locality in the Atane beds of Greenland, which confirms their reference to this genus. The species has a wide range, having been recorded from both the east and west in the United States.

In the Atlantic Coastal Plain it ranges from the middle part of the Raritan formation of New Jersey upward through the Magothy formation of that State and synchronous deposits southward into the basal beds of the Eutaw formation of western Georgia. It is sparingly represented from beds near the base of the Tuscaloosa formation in western Alabama and from this most southerly known occurrence it ranges northward to western Greenland, or over about 38° of latitude, occurring in Georgia, South Carolina, North Carolina, Maryland, New Jersey, New York, and Massachusetts.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Shirleys Mill, Fayette County, Ala. Eutaw formation (basal part), McBrides Ford, Chattahoochee County, Ga.

Collections: U. S. National Museum.

Order MYRICALES.

Family MYRICACEAE.

Genus MYRICA De Candolle.

Myrica emarginata Heer.

Plate XIII, figure 4.

Myrica emarginata Heer, Flora fossilis arctica, vol. 6, Abt 2, p. 66, pl. 41, fig. 2, 1882.

Lesquereux, The flora of the Dakota group, p. 67, pl. 12, fig. 1, 1892.

Newberry, The flora of the Amboy clays, p. 62, pl. 41, figs. 10, 11, 1896.

Berry, New Jersey Geol. Survey Bull. 3, p. 104, pl. 10, fig. 5, 1911.

Heer's description, published in 1882, is as follows:

> M. foliis oblongis, integerrimis, apice emarginatis, basi attenuatis, nervis secundariis subtilissimis.

The Raritan leaves referred to this species by Newberry are not quite typical of this species being somewhat more elongate and lacking the strictly obovate outline shown in the Atane leaves and those from the Dakota sandstone. The remains from the Tuscaloosa formation which are referred to this species are intermediate in character between the Raritan leaves and the type from Greenland, being relatively wider and more robust than the type. They may be characterized as follows: Leaves obovate in outline, widest at the rounded, truncate, and more or less emarginate apex, with entire margins narrowing to the cuneate base. Midrib mediumly stout, flexed in the Alabama material. Secondaries, five thin pairs, subopposite, diverging from the midrib at angles of about 45°, camptodrome. The reference of this species to the genus *Myrica* is entirely problematic. The present species is astonishingly close to a form from Niederschoena, Saxony, described by Engelhardt[1] as *Mimusops ballotaevides*.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, and Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

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[1] Engelhardt, Hermann, Naturwiss. Gesell. Isis in Dresden Abh. 7, Jahrg. 1891, p. 98, pl. 2, fig. 13, 1892.

Myrica longa (Heer) Heer.

Proteoides longus Heer, Flora fossilis arctica, vol. 3, Abt. 2, p. 110, pl. 29, fig. 8b; pl. 31, figs. 4, 5, 1874.

Dawson, Roy. Soc. Canada Trans., vol. 1, sec. 4, p. 22, pl. 2, fig. 8, 1883.

Myrica longa (Heer) Heer, Flora fossilis arctica, vol. 6, Abt. 2, p. 65, pl. 18, fig. 9b; pl. 29, figs. 15–17; pl. 33, fig. 10; pl. 41, fig. 4d, 1882; idem, vol. 7, p. 21, 1883.

Lesquereux, The flora of the Dakota group, p. 67, pl. 3, figs. 1–6, 1892.

Bartsch, Iowa Univ. Lab. Nat. Hist. Bull., vol. 3, p. 180, 1896.

Knowlton, U.S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 314, pl. 39, fig. 7, 1901.

Berry, Torrey Bot. Club Bull., vol. 33, p. 170, 1906.

Leaves of variable size, linear to lanceolate in outline, with a stout midrib, numerous thin, ascending camptodrome secondaries, entire margins, obtusely pointed apex, narrowly decurrent base, and long, stout petiole.

This species was described by Heer as a *Proteoides* and subsequently referred to the genus *Myrica*. It occurs in both the Atane and Patoot beds of Greenland, in the Dakota sandstone of the West, in the Magothy formation of Maryland, and in the Woodbine sand of Texas. It is very common at the Tuscaloosa locality.

Occurrence: Tuscaloosa formation, big gully and upper ravine on the Snow place, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Myrica dakotensis minima Berry, n. var.

Plate XIII, figure 5.

Leaves of very small size, linear or oblong lanceolate in outline, gradually narrowed and decurrent to a short thick curved petiole. Length about 1.5 centimeters. Maximum width, in the middle part of the leaf, about 3.5 millimeters. Margins entire at base, above this closely crenulate. Midrib relatively stout, flat. Secondaries numerous, thin, subparallel, diverging from the midrib at angles of about 45°, curving slightly upward, eventually camptodrome.

This characteristic little leaf is identical with the Dakota sandstone species *Myrica dakotensis* Lesquereux,[1] except that it is only about one-fourth or one-fifth the size of the western form. Its relationship to *Myrica* is questionable.

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County, Ala.

Collection: U. S. National Museum.

Myrica ripleyensis Berry.

Plate XI, figure 2.

Myrica ripleyensis Berry, Torrey Bot. Club Bull., vol. 43, p. 288, 1916.

Leaves of medium size, linear-lanceolate in outline with a gradually narrowed and acuminate tip and a cuneate base. Length about 13 centimeters. Maximum width, in the middle part of the leaf, about 1.75 centimeters. Margins conspicuously serrate toothed, the teeth somewhat irregular in size and disposition; distad they are reduced and close-set. They increase in size proximad until in the median and basal part of the leaf they are large and triangular, the intervening sharp sinuses reaching nearly to the midrib and closely simulating our recent *Comptonia* in character. Texture coriaceous. Petiole not preserved, presumably short and stout. Midrib stout, flexuous. Secondaries numerous, diverging from the midrib at wide angles, about 70°, every third or fourth one straighter than the rest and running to a marginal tooth, the intervening ones somewhat more curved and camptodrome.

This species is exceedingly well marked and is entirely distinct from previously described forms. It resembles closely some of the leaves of our existing *Comptonia peregrina* (Linné) Coulter. It is also much like some of the European Tertiary forms about which so much controversy raged in times past as to whether they were myricaceous or proteaceous.[2] For example, some of the forms of *Comptonia vindobonensis* (Ettingshausen) Berry are similar to the present species. A somewhat similar form is described by Velenovsky from the Bohemian Cretaceous as *Dryandra cretacea*[3] and another by Unger from the Cretaceous of Transylvania as *Comptonites antiquus*.[4] These are both generically distinct from the present species, as shown by their characteristic habit.

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[1] Lesquereux, Leo, The Cretaceous and Tertiary floras, p. 35, pl. 4, fig. 9, 1883.

[2] See Berry, E. W., Living and fossil species of *Comptonia*: Am. Naturalist, vol. 40, pp. 485–520, pls. 1–4, 1906.

[3] Velenovsky, Josef, Die Flora der Bohmischen Kreideformation, pt. 2, p. 1, pl. 1, figs. 1–5, 1883.

[4] Unger, Franz, Ueber einige fossile Pflanzenreste aus Siebenbürgen und Ungarn: K. Akad. Wiss. Wien Sitzungsber., Band 51, pt. 1, p. 2, pl. 1, fig. 1, 1865.

Occurrence: Ripley formation (McNairy sand member), Camden-Paris road, 13 miles northwest of Camden, Benton County, Tenn. (collected by L. W. Stephenson); 2½ miles southwest of Selmer, McNairy County, Tenn. (collected by Bruce Wade).

Collections: U. S. National Museum.

Order FAGALES.

Family FAGACEAE.

Genus DRYOPHYLLUM Debey.

Dryophyllum gracile Debey.

Plate XXXII, figure 2.

Dryophyllum gracile Debey, Feuilles querciformes d'Aix-la-Chapelle, p. 10, figs. 10, 11, 1881.
Berry, Torrey Bot. Club Bull., vol. 43, p. 290, pl. 16, fig. 6, 1916.

Leaves oblong-lanceolate in outline, with a cuneate base and a gradually narrowed tip. Length about 12 centimeters. Maximum width, about midway between the apex and the base, ranging from 1.75 to 2.5 centimeters. Petiole missing. Texture subcoriaceous. Margin with regularly spaced, fairly prominent, nearly straight serrate teeth. Midrib stout, prominent on the lower surface of the leaf. Secondaries thin, regularly spaced, about 15 craspedodrome pairs branching from the midrib at angles of 45° or more, curving regularly upward, subparallel, terminating in the marginal teeth. Tertiaries thin, partly percurrent and partly alternating, joined midway between adjacent secondaries by a zigzag vein.

This well-marked species is represented by five specimens from the Ripley formation of Tennessee. None of these are complete, each showing about two-thirds of a leaf, enough to demonstrate their identity with the European type, which came from the Emscherian of Aix-la-Chapelle, Rhenish Prussia. Additional European occurrences are Tännenberg, Bohemia, and Kieslingswalde, Silesia, all at about the same horizon and probably in the Santonian substage of the Emscherian.

Occurrence: Ripley formation (McNairy sand member), big cut on the Southern Railway near Cypress and 2½ miles southwest of Selmer, McNairy County, Tenn.

Collection: Johns Hopkins University.

Order SALICALES.

Family SALICACEAE.

Genus SALIX Linné.

Salix flexuosa Newberry.

Plate XIII, figure 3.

Salix flexuosa Newberry, Lyceum Nat. Hist. New York City Ann., vol. 9, p. 21, 1868; Illustrations of Cretaceous and Tertiary plants, pl. 1, fig. 4, 1878.
Berry, New Jersey Geol. Survey Ann. Rept. for 1905, p. 145, 1906; Torrey Bot. Club Bull., vol. 33, p. 171, 1906; New Jersey Geol. Survey Bull. 3, p. 115, 1911.
Salix proteaefolia linearifolia Lesquereux, The flora of the Dakota group, p. 49, pl. 44, figs. 1–3, 1892.
Hollick, The Cretaceous flora of southern New York and New England, p. 52, pl. 8, fig. 12, 1906.
Salix proteaefolia flexuosa (Newberry) Lesquereux, The flora of the Dakota group, p. 50, pl. 44, figs. 4, 5, 1892.
Hollick, Torrey Bot. Club Bull., vol. 21, p. 50, pl. 174, fig. 5, 1894; New York Acad. Sci. Ann., vol. 11, p. 59, pl. 4, fig. 5a, 1898; The Cretaceous flora of southern New York and New England, p. 51, pl. 8, figs. 5, 6a; pl. 37, fig. 8b, 1906.
Berry, New York Bot. Garden Bull., vol. 3, p. 67, pl. 48, fig. 12; pl. 51, fig. 2, 1903.

Leaves narrow, linear-lanceolate in outline, equally pointed at both ends, short petioled, ranging from 5 to 10 centimeters in length, and from 8 to 13 millimeters in maximum width. Margins entire. Midrib stout below, tapering above, somewhat flexuous in many specimens. Secondaries more or less remote, about 10 alternate pairs, branching from the midrib at angles ranging from 35° to 45°, camptodrome, of fine caliber, many of them obsolete.

This species was described by Newberry from the Dakota sandstone in 1868. Lesquereux subsequently made it one of the varieties of his *Salix proteaefolia*, although it is obviously entitled to independent specific rank. It is of rare occurrence in the Raritan formation of New Jersey, where it is first found in the uppermost beds at South Amboy, N. J., and it is preeminently a species which characterizes the Magothy formation from New Jersey to Maryland and homotaxial horizons to the south. It is recorded from the Magothy formation from Marthas Vineyard to Potomac River.

It occurs in the Black Creek formation of North and South Carolina, and in the Middendorf arkose member of the Black Creek in the latter State. In Georgia, though not especially abundant, characteristic leaves of this species are found in the lower part of the Eutaw formation in the western part of the State. In Alabama it is very common at a relatively large number of localities from the base to the top of the Tuscaloosa formation.

Occurrence: Tuscaloosa formation, Shirleys Mill, Glen Allen, Fayette County; big gully and upper ravine on the Snow place; Robertson's upper landing, and Sanders Ferry Bluff, gully at Tuscaloosa, Tuscaloosa County; Whites Bluff, Greene County; near Maplesville, Chilton County, Ala. Eutaw formation, McBrides Ford, Chimney Bluff, Broken Arrow Bend, Chattahoochee County, Ga.

Collections: U. S. National Museum.

Salix lesquereuxii Berry.

Salix lesquereuxii Berry, Torrey Bot. Club Bull., vol. 36, p. 252, 1909; idem, vol. 37, pp. 21, 194, 1910; New Jersey Geol. Survey Bull. 3, p. 114, 1911.

Salix proteaefolia Lesquereux, Am. Jour. Sci., 2d ser., vol. 46, p. 94, 1868 (not Forbes); The Cretaceous flora, p. 60, pl. 5, figs. 1–4, 1874; The Cretaceous and Tertiary floras, p. 42, pl. 1, figs. 14–16, pl. 16, fig. 3, 1883; The flora of the Dakota group, p. 49, 1892.

Newberry, The flora of the Amboy clays, p. 66, pl. 18, figs. 3, 4, 1896.

Kurtz, Rev. Mus. La Plata, vol. 10, p. 51, 1902.

Berry, New Jersey Geol. Survey Ann. Rept. for 1905, p. 139, 1906; Torrey Bot. Club Bull., vol. 33, p. 171, pl. 7, fig. 2, 1906; Johns Hopkins Univ. Circ., new ser., No. 7, p. 81, 1907.

Salix proteaefolia longifolia Lesquereux, The flora of the Dakota group, p. 50, pl. 44, fig. 9, 1892.

Bartsch, Univ. Iowa Lab. Nat. Hist. Bull., vol. 3, p. 179, 1896.

Proteoides daphnogenoides Heer. Newberry, The flora of the Amboy clays, p. 72 (part), pl. 32, fig. 11, 1896.

Dewalquea groenlandica Heer. Newberry, The flora of the Amboy clays, p. 129 (part), pl. 41, fig. 12, 1896.

Leaves ovate-lanceolate in outline, somewhat more acuminate above than below, variable in size, ranging from 6 to 12 centimeters in length, and from 1.1 to 2.2 centimeters in greatest width, which is usually slightly below the middle. Petiole stout, much longer than in *Salix flexuosa*, having a maximum length of 1.2 centimeters. Midrib stout below, tapering above. Secondaries numerous, in some specimens as many as 20 pairs; they branch from the midrib at angles of about 45° and are parallel and camptodrome.

This species is exceedingly variable, as might be expected in a *Salix*, and Lesquereux established several varieties, of which at least one, *linearifolia*, is referable to *Salix flexuosa* Newberry. Some of Lesquereux's forms are distinguishable with difficulty from *Salix flexuosa*, and this is especially shown in the leaves which he figures in Plate I of his "Cretaceous and Tertiary floras." They are, however, larger and somewhat more robust, of a thicker texture, and broadest near the base, from which they taper upward to an exceedingly acuminate tip. In general *Salix lesquereuxii* is a relatively much broader, more ovate form with more numerous and better seen secondaries and a longer petiole.

This species is an exceedingly abundant Cretaceous type in both the East and the West, ranging chronologically in the Coastal Plain from the base of the Raritan formation to the top of the Tuscaloosa formation, and possibly through the Eutaw formation as well. It is abundant in the Magothy and Black Creek formations, including the Middendorf arkose member of the Black Creek. In the west it is common in the Dakota sandstone. It is one of the forms recorded by Kurtz from the Upper Cretaceous of Argentina, indicating, if the identification is correct, a very considerable migration during the early Upper Cretaceous. In Alabama it ranges from the bottom to the top of the Tuscaloosa formation.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, Fayette County; big gully on the Snow place, left bank of Black Warrior River at Tuscaloosa; Sanders Ferry Bluff, Cottondale, and gully in Tuscaloosa, Tuscaloosa County, Ala. Eutaw formation, Chimney Bluff, Chattahoochee County, Ga.

Collections: U. S. National Museum.

Salix eutawensis Berry.

Salix eutawensis Berry, Torrey Bot. Club Bull., vol. 37, p. 193, pl. 22, figs. 1-11, 1910; U. S. Geol. Survey Prof. Paper 84, p. 109, pl. 19, fig. 3, 1914; Torrey Bot. Club Bull., vol. 43, p. 289, 1916.

This characteristic species was recently described in the papers cited and the discussion need not be repeated here.

Occurrence: Eutaw formation (basal part), Broken Arrow Bend, Chattahoochee County, Ga.; (Coffee sand member), cut on the Nashville, Chattanooga & St. Louis Railway, just east of Parsons, Decatur County, Tenn.

Collections: U. S. National Museum.

Salix meekii Newberry.

Salix meekii Newberry, Lyceum Nat. Hist. New York City Ann., vol. 9, p. 19, 1868; The later extinct floras of North America, p. 58, pl. 2, fig. 3, 1898.
Lesquereux, The Cretaceous and Tertiary floras, p. 42, 1883.
Hollick, New York Bot. Garden Bull., vol. 2, p. 404, pl. 41, fig. 1, 1902; New York Acad. Sci. Trans., vol. 16, p. 130, pl. 13, figs. 3, 4, 1897; The Cretaceous flora of southern New York and New England, p. 51, pl. 8, figs. 1c, 8, 9, 1906.
Berry, New York Bot. Garden Bull., vol. 3, p. 68, 1903.
Salix cuneata Newberry, Lesquereux, Illustrations of Cretaceous and Tertiary plants, pl. 1, figs. 2, 3, 1878.
Salix proteaefolia lanceolata Lesquereux, The flora of the Dakota group, p. 50, pl. 64, figs. 6–8, 1892.
Hollick, New York Acad. Sci. Ann., vol. 11, p. 59, pl. 4, fig. 4, 1898; The Cretaceous flora of southern New York and New England, p. 52, pl. 8, figs. 1a, 2–4, 1906.

The original description of this species, published by Newberry in 1868, is as follows:

> Leaves petioled, thin and delicate, lanceolate, acute at both ends, nervation delicate, midrib slender, secondary nerves fine, springing from the medial nerve at an angle of 35°, gently arched and anastomosing near the margins; network of tertiary veins somewhat lax but composed of nervules of such tenuity as to be rarely visible.

This is one of the historic Dakota sandstone plants, a sketch of which was submitted to Heer by Meek in the early days of the study of that formation. It has since been recorded from a large number of localities in the Magothy formation of the Atlantic Coastal Plain and from strata of supposed Colorado age in western Iowa.[1] It is not common in the Tuscaloosa flora but is represented by typical thin lanceolate leaves. It is doubtfully distinct from the associated *Salix lesquereuxii* Berry.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Genus POPULUS Linné.

Populus hyperborea Heer.

Populus hyperborea Heer, Flora fossilis arctica, vol. 3, pt. 2, p. 106, pl. 27, fig. 8d; pl. 29, figs. 6–9; pl. 30, fig. 2b, 1874; idem, vol. 6, pt. 2, p. 64, pl. 17, figs. 6, 7; pl. 21, fig. 1a, 1882.
Lesquereux, The flora of the Dakota group, p. 43, pl. 3, figs. 9–11; pl. 8, fig. 1; pl. 47, fig. 5, 1892.
Bartsch, Iowa Univ. Lab. Sci. Bull., vol. 3, p. 179, 1896.

Leaves ovate to elliptical in outline with a broadly rounded apex and a broadly rounded to cuneate base. Length ranges from 4 to 7 centimeters. Maximum width, in middle part of the leaf, 5 to 6 centimeters. Margins entire. Texture coriaceous. Petiole stout, curved, about 2 centimeters long. Midrib stout. Secondaries stout, 5 or 6, opposite to alternate pairs, diverging from the midrib at acute angles and somewhat crowded toward the base of the midrib, camptodrome, the lower ones giving off outwardly directed camptodrome tertiaries. Balance of tertiaries thin, percurrent.

This species was described by Heer from very fragmentary material from the Atane beds of West Greenland. Lesquereux described much more complete material from the Dakota sandstone, in which this species is common both in Kansas and Iowa. The species is represented by considerable material from the Tuscaloosa formation that is obviously identical with that from Kansas with which comparisons can be made much more conclusively than with the figures of the Greenland specimens.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Genus POPULITES Lesquereux.

Populites tuscaloosensis Berry, n. sp.

Plate XIII, figure 2.

Leaves ovate-elliptical in outline with an obtusely rounded apex and a cuneate base.

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[1] Stanton, T. W., The Colorado formation and its invertebrate fauna: U. S. Geol. Survey Bull. 106, p. 21, 1893.

Length about 7 centimeters. Maximum width about 5.25 centimeters in the basal half of the leaf. Texture subcoriaceous. Margin entire below, becoming undulate or slightly repand above by the development of a very shallow rounded sinus between the tips of some of the secondaries. Midrib stout, slightly flexuous. Secondaries stout, becoming thin distad, about five alternate, parallel, craspedodrome pairs; they branch from the midrib at regular intervals at angles of almost exactly 45° and pursue a straight course to the margins. Tertiaries mostly percurrent, those which run outward from the basal secondaries apparently running directly to the margin.

This species is entirely distinct from any of the previously described species of *Populites* which are so numerous and variable in the Dakota sandstone. It is closest to some of the forms of *Populites litigiosus* of Lesquereux, which both Heer and Newberry referred directly to the genus *Populus*. Knowlton has described a species which he names *Populus cretacea*[1] and which comes from the Montana group of Montana. In some of its forms[2] this species is similar to *Populites tuscaloosensis*. The other figured forms are not at all like the Tuscaloosa leaves. A comparison of the similar form of *Populus cretacea* with the Tuscaloosa species shows that the latter is pinnatifid and presents no indication of any differentiation in the lower secondaries. The secondaries are stouter; the teeth are much feebler, less numerous, less acute, and never present except at the apex of secondaries. The tertiaries are more regularly percurrent.

The two species are believed to be entirely distinct, and the Alabama form is clearly allied with the Dakota sandstone forms of *Populites* in all of its essential characters.

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County; gully at Tuscaloosa, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Order URTICALES.

Family MORACEAE.

Genus FICUS Linné.

Ficus krausiana Heer.

Ficus krausiana Heer. Allg. schweiz. Gesell. gesammt. Naturwiss. Bern Neue Denkschr., Band 23, p. 15, pl. 5, figs. 3–6, 1869.

Lesquereux, The flora of the Dakota group, p. 81, pl. 1, fig. 5, 1892.

Hollick, Geol. Soc. America Bull., vol. 7, p. 13, 1895; New York Acad. Sci. Ann., vol. 11, p. 59, pl. 3, fig. 1, 1898; The Cretaceous flora of southern New York and New England, p. 58, pl. 9, fig. 9, pl. 10, figs. 1–3, 1906.

Berry, Torrey Bot. Club Bull., vol. 33, p. 172, 1906; idem, vol. 43, p. 291, 1916.

Ficus beckwithii Lesquereux, The Cretaceous and Tertiary floras, p. 46, pl. 16, fig. 5; pl. 17, figs. 3, 4, 1883.

Ficus suspecta Velenovsky, Die flora der böhmischen Kreideformation, pt. 4, p. 10, pl. 5, figs. 6, 9, 1885.

Ficus atavina Heer (?). Hollick, New York Acad. Sci. Trans., vol. 11, p. 103, pl. 4, figs. 4, 6, 1892.

Leaves of large size, ovate-lanceolate in outline, broadest at or below the middle. Apex and base acutely pointed, the apex often extended and attenuated. Petiole and midrib stout. Secondaries regular, open, thin, ascending, camptodrome, branching from the midrib at angles of 45° or more. Length about 17 centimeters. Greatest width about 4 centimeters.

This well-known Upper Cretaceous species was described originally from the Cenomanian of Moravia, and it has been subsequently recorded from a large number of American localities. In the West it occurs in the Dakota sandstone; in the East it is common from Marthas Vineyard to Alabama and is present between these limits in Maryland, North Carolina, South Carolina, and Georgia. These occurrences are all in beds of Magothy age or younger. In both North Carolina and South Carolina fruits of *Ficus* are associated with this species, but whether they are to be referred to it or to some of the other rather numerous species of *Ficus* which occur at the same localities can not be determined. The present species is one of the commonest post-Raritan fossils in the Coastal Plain, and it is especially abundant in the Middendorf arkose member of the Black Creek formation of South Carolina. In Alabama it is not uncommon in the Tuscaloosa formation, and it persists into the basal beds of the Eutaw formation in Hale County.

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[1] Knowlton, F. H., U. S. Geol. Survey Bull. 257, p. 138, pl. 17, figs. 1–5, 1905.

[2] Idem, pl. 17, fig. 1.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, Fayette County; Cottondale (?), Sanders Ferry Bluff, and upper ravine on the Snow place, Tuscaloosa County, Ala. Eutaw formation (basal part), 2 miles south of Havana, Hale County, Ala.; Chimney Bluff, Chattahoochee County, Ga.; Coffee sand member of Eutaw formation, Coffee Bluff, Hardin County, Tenn.

Collections: U. S. National Museum.

Ficus crassipes (Heer) Heer.

Proteoides crassipes Heer, Flora fossilis arctica, vol. 3, Abt. 2, p. 110, pl. 31, figs. 6–8a, 1874.

Ficus crassipes (Heer) Heer, Flora fossilis arctica, vol. 6, Abt. 2, p. 70, pl. 17, fig. 9a, pl. 24, figs. 1, 2.

Lesquereux, The flora of the Dakota group, p. 79, pl. 13, fig. 3, 1892.

Berry, Torrey Bot. Club Bull., vol. 33, p. 172, 1906; idem, vol. 43, p. 291, 1916.

Ficus daphnogenoides (Heer) Berry, Johns Hopkins Univ. Circ., new ser., No. 7, p. 81, 1907.

Leaves entire, narrowly lanceolate in outline, about equally tapering to the acuminate apex and base. Length 12 to 20 centimeters. Greatest width, which is in the middle part of the leaf, 1.8 to 2.5 centimeters. Texture coriaceous. Midrib stout, in many specimens extraordinarily so. Secondaries thin, open, ascending, camptodrome.

This species was described originally from the Atane beds of western Greenland; the first rather fragmentary specimens collected suggested a relationship with the genus *Proteoides*. Subsequently the original describer referred it to *Ficus*, where it undoubtedly belongs. Lesquereux has recorded it from the Dakota sandstone of the West, and it is common in the Magothy formation of the northern Atlantic Coastal Plain and in the Black Creek formation of North Carolina. It persists into the Eutaw formation of Georgia and is especially common in the Middendorf arkose member of the Black Creek formation of South Carolina. It is not very common in the Tuscaloosa formation and is a species which is especially characteristic of the post-Raritan and pre-Matawan horizons of eastern North America.

The leaf substance is partially preserved in the Sanders Bluff material and shows in microscopic preparations the spiral tracheids of the leaf veins and numerous lactiferous cells. Both lower and upper epidermal layers are well preserved. They are thin and highly cuticularized, the epidermis consisting of very small, nearly equilateral, quadrangular thick-walled cells. The stomata are few and scattered and are confined to the lower surface. They consist of two rather thin, sausage-shaped guard cells set on edge—that is, much higher than wide, the length equal to two epidermal cells.

Occurrence: Tuscaloosa formation, Sanders Ferry Bluff, and big gully and upper ravine on the Snow place, Tuscaloosa County, Ala. Eutaw formation, Chimney Bluff, Chattahoochee County, Ga. (Coffee sand member), Coffee Bluff, Hardin County, Tenn.

Collections: U. S. National Museum.

Ficus georgiana Berry.

Ficus georgiana Berry, U. S. Geol. Survey Prof. Paper 84, p. 111, pl. 20, fig. 1, 1914.

I have recently described this form from the Eastern Gulf region in the paper cited.

Occurrence: Ripley formation (Cusseta sand member), near Buena Vista, Marion County, Ga.

Collection: U. S. National Museum.

Ficus ovatifolia Berry.

Ficus ovatifolia Berry, Torrey Bot. Club Bull., vol. 36, p. 253, 1909; U. S. Geol. Survey Prof. Paper 84, p. 111, pl. 19, figs. 5–7, 1914.

Ficus ovata Newberry, The flora of the Amboy clays, p. 70, pl. 24, figs. 1–3, 1896 (not Don).

I have recently discussed this species for the Eastern Gulf area in the paper cited. It may be distinguished from the closely allied *Ficus woolsoni* by its greater elongation and narrower base.

Occurrence: Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga.; (Coffee sand member), Coffee Bluff, Hardin County, Tenn.

Collections: U. S. National Museum.

Ficus daphnogenoides (Heer) Berry.

Plate XIII, figures 6, 7.

Proteoides daphnogenoides Heer, Phyllites crétacées du Nebraska, p. 17, pl. 4, figs. 9, 10, 1866.
Lesquereux, The Cretaceous flora, p. 85, pl. 15, figs. 1, 2, 1874; The flora of the Dakota group, p. 90, 1892.
Hollick, New York Acad. Sci. Trans., vol. 11, p. 98, pl. 3, figs. 1, 2, 1892; idem, vol. 12, p. 36, pl. 2, figs. 4, 9, 13, 1893; Torrey Bot. Club Bull., vol. 21, p. 52, pl. 177, fig. 1, 1894; The Cretaceous flora of southern New York and New England, p. 59, pl. 12, figs. 1–5, 1906.
Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894 (determined by Ward).
Newberry, The flora of the Amboy clays, p. 72, pl. 17, figs. 8, 9; pl. 32, figs. 11, 13, 14; pl. 33, fig. 3; pl. 41, fig. 15, 1896.
Berry, New York Bot. Garden Bull., vol. 3, p. 74, pl. 51, figs. 6–9, 1903.
Ficus daphnogenoides (Heer) Berry, Torrey Bot. Club Bull., vol. 32, p. 327, pl. 21, 1905; idem, vol. 33, p. 173, pl. 7, fig. 5, 1906; idem, vol. 34, p. 194, pl. 11, figs. 10, 11, 1907.
Ficus proteoides Lesquereux, The flora of the Dakota group, p. 77, pl. 12, fig. 2, 1892.
Eucalyptus? attenuata Newberry, The flora of the Amboy clays: New Jersey Geol. Survey Bull. 3, p. 122, pl. 12, fig. 4, 1911; pl. 16, fig. 5 (not figs. 2, 3), 1896.

Heer's description, published in 1866, is as follows:

> Les feuilles sont coriaces, à la base atténuées, entières; la nervure médiane est forte; elle porte deux nervures secondaires faibles, acrodromes, qui sont presque parallèles au limbe; mais elles ne sont pas opposées, comme chez les *Daphnogene* et *Cinnamomum*.

This species was described by Heer from the Dakota sandstone of Nebraska, and was based upon very incomplete material. His specimens have some long ascending secondaries, but Lesquereux's more complete specimens from the same formation and region show that these secondaries were not acrodrome but camptodrome. The species in this feature, and also in other respects, differs from *Protea* and its allies, which are more coriaceous and have the secondaries branching at acute angles and massed toward the generally apetiolate base. When compared with the genus *Ficus* it is found to closely resemble a number of different species from such widely separated localities as Central and South America and the Celebes. Especially among the Mexican and Central American forms are very similar leaves seen; for example, *Ficus fasciculata* Watson, *Ficus lancifolia* Hooker and Arnott, *Ficus ligustrina* Kunth and Bouché, and especially *Ficus sapida* Miquel, which has much the same outline and consistency, the same prominent midrib, and the same venation. When the fossil forms are placed in the genus *Ficus*, where they properly belong, they find their affinity in the group which includes, among others, such species as *Ficus elongata* Hosius, *Ficus berthoudi* Lesquereux, *Ficus suspecta* Velenovsky, and *Ficus krausiana* Heer.

This species has been found to be quite variable in size, ranging in length from 11 to 22 centimeters and in width from 1.9 to 3.7 centimeters. It is usually widest in the lower half of the leaf, although in some specimens the base is quite narrow and the widest part is toward the middle. In all unequivocal material the upper half of the leaf is narrow and is produced as a long, slender, commonly recurved tip, which is one of the characteristic features of the species. This tip is strictly comparable with the "dripping points" developed on various leaves in the modern Tropics where precipitation is heavy.

Ficus daphnogenoides is a widespread and common form, ranging from Marthas Vineyard to Alabama in eastern North America and from the Northwest Territory to Kansas and Nebraska in the Western Interior region.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, Fayette County; Cottondale, big gully and upper ravine on the Snow place, and gully at Tuscaloosa, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Ficus inaequalis Lesquereux.

Plate XII, figure 1.

Ficus inaequalis Lesquereux, the flora of the Dakota group, p. 82, pl. 49, figs. 6–8; pl. 50, figs, 3, 6, 1892.
Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.
Bartsch, Iowa Univ. Lab. Nat. Hist. Bull., vol. 3, p. 180, 1896.
Berry, Torrey Bot. Club Bull., vol. 34, p. 194, pl. 12, figs. 2, 3, 1907.

Leaves broadly ovate-acuminate in outline, many of them inequilateral. Size variable, ranging from 4 to 12 centimeters in length by 2 to 4.5 centimeters in maximum width, which is slightly below the middle, averaging about 8 centimeters in length by 3 to 3.5 centimeters in maximum width. From the middle the entire margins curve downward in a full curve to the slightly decurrent base and upward to the more or less extended and commonly falcate-acuminate apex. Petiole short and stout, 2.5 centimeters long in the largest specimen seen. Midrib stout below, becoming much attenuated in the acumen. Secondaries numerous, mostly thin, somewhat irregularly spaced, branching from the midrib at angles of about 45°, and curving upward, regularly camptodrome. In some specimens one of the lower secondaries on either or both sides may be larger than the rest, giving the leaf the appearance of being triple veined. Tertiaries fine, of the usual *Ficus* type.

This handsome species was described originally from the Dakota sandstone of Kansas. It was subsequently recognized by Ward in collections from the Tuscaloosa formation, by Bartsch in the Dakota sandstone of Iowa, and by the writer in the Black Creek formation of North Carolina. The acuminate apex, though not developed to the conspicuous extent that it is in some of the other members of the Tuscaloosa flora, fully merits the appellation of "dripping point." Its presence in so many different forms in this flora is a clear indication of humidity and heavy rainfall.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Ficus shirleyensis Berry n. sp.

Plate XIII, figure 8.

Leaves ovate-acuminate in outline, about 10 centimeters in length by about 3.5 centimeters in maximum width, which is at a point about one-third of the distance from the base to the tip. Margins full and curved at the broadest part of the blade, becoming incurved and decurrent at the base and incurved upward to the narrow, extended, acuminate tip. Petiole stout, short. Midrib stout, curved. Secondaries numerous, thin, approximately parallel, camptodrome; they branch from the midrib at angles of about 45°, those in the broader part of the blade sweeping upward in a wide curve, approximately parallel with the lower lateral margin, and those in the acumen becoming short and nearly straight. Tertiaries fine, of the usual type found in *Ficus* leaves with the habit of the present species.

This form is exceedingly striking and graceful, and it is entirely distinct from any known Cretaceous species, although it may be readily matched by a number of modern tropical American species. It resembles to a certain extent the contemporaneous species *Ficus inaequalis* Lesquereux, and *Ficus daphnogenoides* (Heer) Berry, being intermediate in its characters. Thus it is relatively shorter and broader than *Ficus daphnogenoides* and relatively larger than *Ficus inaequalis* and is more elegantly proportioned than either of these, at the same time preserving the same general facies. The long acumen or "dripping point," which has been commented upon in connection with other members of the Tuscaloosa flora, is exceedingly well developed and may be duplicated in species now growing in the tropical rain forests of northern South America. The preservation of these features in the present species also affords a clear indication of the quiet waters in which the Tuscaloosa sediments were laid down at this point and further indicates that the form was a marginal species and was not brought down to the basin of sedimentation by rivers from some inland habitat.

Among previously described fossil plants the present species bears a close resemblance to the larger leaves of the form from the Cenomanian of Bohemia described by Velenovsky[1] as *Cassia melanophylla*.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Ficus woolsoni Hollick.

Plate XII, figure 2.

Ficus woolsoni Hollick, New York Acad. Sci. Trans., vol. 12, p. 33, pl. 2, figs. 1, 2c, 1892; New York Acad. Sci. Ann., vol. 11, p. 419, pl. 37, fig. 9, 1898; The Cretaceous flora of southern New York and New England, p. 59, pl. 11, figs. 5, 6, 1906.

Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.

Newberry, The flora of the Amboy clays, p. 70, pl. 20, fig. 3; pl. 23, figs. 1–6, 1896.

Berry, New York Bot. Garden Bull., vol. 3, p. 74, pl. 47, fig. 7, 1903; Torrey Bot. Club Bull., vol. 33, p. 172, 1906; New Jersey Geol. Survey Ann. Rept. for 1905, p. 119, 1906; New Jersey Geol. Survey Bull. 3, p. 124, pl. 12, figs. 1, 2, 1911.

Leaves broadly ovate to cordate in outline, 5 to 10 centimeters in length, by 3.25 to 10

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[1] Velenovsky, Josef, Die Flora der böhmischen Kreideformation, pt. 4, p. 5, pl. 8, figs. 1, 2, 8, 9, 11, 12, 1885. See especially fig. 1.

centimeters in breadth, with a usually acute apex and a cordate to a rounded, more or less decurrent base. Margin entire. Principal veins three, the midrib being the stoutest. The laterals branch at a variable angle from the top of the petiole, traverse considerably more than the basal half of the leaf, and join the camptodrome secondaries above; they give off on the outside numerous camptodrome branches, the lowest of which in some specimens branch from their extreme base, so that basal fragments of these leaves have the appearance of *Hedera primordialis* Saporta.

As I have previously pointed out, this species has many points of resemblance to *Ficus ovatifolia* Berry but is decidedly shorter and broader, with a more orbicular outline and a marked tendency toward a cordate base. It was evidently of a more coriaceous texture, as the finer venation is obsolete.

Ficus woolsoni is a much more abundant form in the Raritan formation of New Jersey than *Ficus ovatifolia*, and it has a considerably wider distribution, for it is recorded from Staten Island and from North Carolina and Georgia. It is also present in the Magothy formation in the New Jersey-Maryland region.

Occurrence: Tuscaloosa formation, Glen Allen and Shirleys Mill, Fayette County; gully at Tuscaloosa, Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Ficus alabamensis Berry, n. sp.

Plate XIV, figure 5.

Leaves of large size, cordate in outline, about 15 centimeters in length by 13 to 14 centimeters in greatest width, which is in the basal half of the leaf. Margin entire, with wide shallow indentations at irregular intervals. Apex pointed. Lateral margins rounded to the broad, truncate (not emarginate) base. Petiole short and stout, about 2.5 centimeters in length, swollen below and then constricted at the point of attachment. Midrib stout below, becoming greatly reduced and more or less curved distad. Secondaries stout, about seven subopposite pairs, branching from the midrib at angles of 45° or more, and curving upward, camptodrome; those in upper half of the leaf much reduced. Tertiaries camptodrome along the margin, transverse and curved between the secondaries. Texture somewhat coriaceous, but leaf substance not especially thick.

This handsome species is based upon splendid material from Shirleys Mill, Ala., near the base of the Tuscaloosa formation, and is entirely distinct from any known Cretaceous forms. Although its secondary venation is pinnate, it belongs with the palmate-veined species of *Ficus* represented in the Tuscaloosa by *Ficus woolsoni*, which is truly tri-veined and smaller than the present species. It bears the same relation to this type as the pinnately veined species of *Populus* bear to those which are clearly palmate in their venation.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Ficus fontainii Berry, n. sp.

Plate XI. figure 3.

Leaves of medium to small size, broadly elliptical and more or less inequilateral in general outline, with a shallow rounded sinus on each side in the upper part, giving them a trilobate form, with full rounded lateral lobes and a narrow rounded apical lobe. Basal margins full and rounded, slightly decurrent. Length ranging from 7.5 to 11 centimeters. Maximum width, about halfway between the apex and the base, 5 to 8 centimeters. Margins entire. Texture coriaceous. Petiole stout, tapering proximad, about 1.25 centimeters in length. Midrib stout and curved, prominent on the lower surface of the leaf. Secondaries pinnate, irregularly spaced, becoming close together in the basal part of the leaf; they are stout, rather prominent on the lower surface of the leaf and rather irregular in their courses; six to eight mostly alternate pairs diverge from the midrib at acute angles and pursue a rather straight ascending course, forking in some specimens but as a rule regularly camptodrome except the second or third one from the base, which terminates at the apex of the lateral lobe. Tertiaries thin, mostly percurrent and subparallel.

This handsome and characteristic species is unfortunately represented by fragmentary material, the most complete leaf being the rather small one figured. This material was collected in 1888 by W. M. Fontaine, for whom it is named. It suggests somewhat the American late Cretaceous and early Eocene forms that have been referred to *Ficus tiliaefolia* (Alexander Braun) Heer, as well as the two Dakota sandstone species *Benzoin masoni* (Lesquereux) Knowlton and *Benzoin venustum* (Lesquereux) Knowlton, both of which, however, are palmately triveined, with deep narrow sinuses, ovate lobes, and cuneate bases. It is, however, typically *Ficus*-like in the characters of its venation and perfectly distinct from previously described forms.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County; Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Order PLATANALES.[1]

Family PLATANACEAE.

Genus PLATANUS Linné.

[Species plantarum, p. 999, 1753.]

Platanus asperaeformis Berry, n. sp.

Plate XVI, figure 1.

Platanus newberryana Heer, Flora fossilis arctica, vol. 7, p. 28 (part), pl. 59, fig. 2, 1883 (not remainder of Heer's figures).

Leaves of medium size, orbicular in general outline, somewhat trilobate, with acute apex and cordate (?) base. Primaries three in number, of about equal prominence, the laterals branching from the midrib at angles of about 45°, slightly curved, terminating in the pointed tips of the lateral lobes, which are but slightly extended. Secondaries thin, numerous, craspedodrome. Tertiaries of the usual *Platanus* type. Margin prominently toothed. Teeth numerous, markedly aquiline-serrate, those at the termination of the secondaries enlarged.

This species is somewhat similar but more ample than the Dakota sandstone species, *Platanus newberryana* Heer,[2] and has a somewhat different margin. However, the leaf from western Greenland identified by Heer as *P. newberryana* and cited above seems to differ from it and to be identical with the present species, indicating the remarkable range from Alabama to Greenland. As the occurrence in Greenland is in a somewhat younger horizon, the species may have migrated northward, although it has always been assumed that the usual direction of migration of the Cretaceous floras was from the north southward.

The present species is not common and is associated with *Platanus shirleyensis* Berry, from which it shows well-marked differences. It is named in allusion to its great resemblance and possible ancestral relation to *Platanus aspera* Newberry,[3] an upper Eocene species of the Pacific Coast region. There is also a somewhat more distant resemblance to the Fort Union species *Platanus raynoldsii* Newberry.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Platanus shirleyensis Berry, n. sp.

Plate XV, figures 1–5.

Leaves of small and medium size, ranging from 5 to 15 centimeters in length, by 3.5 to 12 centimeters in maximum width, at a point about halfway between the apex and the base. Trilobate, the median lobe ovate, the lateral lobes directed outward and upward, conical in form. Lateral sinuses, narrowly rounded, extending less than half the distance to the base, which is cuneate or slightly decurrent. Petiole stout, enlarged and partly sheathing proximad, as in the leaves of the modern species, variable in length, only 1 centimeter long in the smallest specimen figured but 4 centimeters long in other specimens which were collected. Lateral primaries, one on each side, stout, of the same caliber as the midrib, from which they branch either at or above its base, their relative position being determined by the amount of decurrence or truncation of the basal part of the leaf blade. Angle of divergence with the midrib about 30°. They terminate at the tips of the lateral lobes. Secondaries somewhat stout and fairly numerous, regularly spaced and approximately parallel in the larger leaves but more variable in this respect in small leaves; they diverge at angles of about 45°, pursue a more or less slightly curved course, and terminate in the marginal teeth, hence they are craspedodrome.

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[1] I follow Griggs (Torrey Bot. Club Bull., vol. 36, pp. 389-395, 1909) in removing Platanus from the Rosales and making it the type of an order in the Apetalae next above the Urticales.

[2] Heer, Oswald, Phyllites crétacées du Nebraska, p. 16, pl. 1, fig. 4, 1866.

[3] Newberry, J. S., U. S. Nat. Mus. Proc., vol. 5, p. 509, 1882; U. S. Geol. Survey Mon. 35, p. 102, pl. 42, figs. 1-3; pl. 44, fig. 5; pl. 59, fig. 3, 1898.

Margins entire below, especially in the smaller leaves, above with broad-pointed serrate teeth directed upward, one to each secondary and with intermediate less prominent teeth. Tertiary venation typical of *Platanus*. Some of the leaves are infested with a spot fungus, *Sphaerites alabamensis* Berry.

This species is totally unlike any previously described *Platanus* and exhibits a rather wide range of variations. The small forms in particular, in their remote teeth, some of them crenate, and in the character of their base suggest some forms of *Sassafras* or of *Aralia wellingtoniana* Lesquereux. They are, however, connected by numerous intermediate forms with leaves that are typically those of *Platanus*, a relationship emphasized by the character of the petiole in both large and small forms.

The present species suggests somewhat *Platanus asperaeformis* Berry, which occurs with it in Fayette County, but the form is relatively narrower and longer, the teeth are much less aquiline, the lobes are more pronounced, and the base is different. Another species which resembles *Platanus shirleyensis* is *Platanus kümmelii*, which I have described from the Magothy formation of New Jersey.[1] Some of the leaves of *P. kümmelii*, which is abundantly represented by both leaves and fruit, are very close to the present species, although the typical form is that of a much larger, more prominently lobed and toothed, and more modern-looking leaf.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Platanus latior (Lesquereux) Knowlton.

Platanus aceroides? Goeppert var. *latior* Lesquereux, Am. Jour. Sci., 2d ser., vol. 46, p. 97, 1868.

Platanus latior (Lesquereux) Knowlton, U.S. Geol. Survey Bull. 152, p. 170, 1989; U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 314, 1901.

Platanus primaeva Lesquereux, The Cretaceous flora, p. 69, pl. 7, fig. 2; pl. 26, fig. 2, 1874; The flora of the Dakota group, p. 72, pl. 8, figs. 7, 8b; pl. 10, fig. 1, 1892.

Leaves large, palmately trilobate broadly rhomboidal in outline. Length of specimen from Alabama about 17 centimeters. Maximum width about 15 centimeters. Margins somewhat irregularly dentate, entire at the broadly cuneate base. Lateral lobes short; intervening sinuses scarcely differentiated. Petiole long and stout. Primaries stout, three in number, diverging at or near the base in the material from Alabama, but commonly suprabasilar in the forms from the Dakota sandstone. Venation strictly platanoid. Texture coriaceous.

This fine large species is very abundant in the Dakota sandstone of Kansas, Nebraska, and Minnesota, and Lesquereux differentiated three varieties, namely, *integrifolia*, *subintegrifolia*, and *grandidentata*. The forms from Alabama are closer to the type than they are to any of the varieties.

The species appears to have been common near Cottondale, and it occurs in the Woodbine sand of Texas, according to Knowlton. It is readily distinguishable from the other two Tuscaloosa species of *Platanus* and in size and general appearance suggests *Platanus kümmelii* Berry [1] of the Magothy formation of New Jersey but is more entire and less prominently toothed.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Platanus ripleyensis Berry, n. sp.

Plate XXXII, figure 6.

Leaves small, trilobate, about 7 centimeters in length by 8 centimeters in maximum width from tip to tip of the lateral lobes. Base cuneate or slightly decurrent. Sinuses open, shallow, extending less than halfway to the base. Margins entire below, elsewhere with large serrate teeth directed distad. Petiole stout. Primaries three, suprabasilar. Secondaries mostly craspedodrome—a few intermediate ones camptodrome. Tertiaries thin, numerous, typically platanoid.

This species is a very modern-looking *Platanus*, and is readily distinguishable from the known Upper Cretaceous species. It is also clearly different from the imperfect material from the near-by locality on Cowikee Creek referred to *Platanus* sp. In its general facies it might readily be mistaken for a small leaf of *Platanus orientalis* or *Platanus occidentalis* or for the common Miocene species *Platanus*

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[1] Berry, E. W., New Jersey Geol. Survey Ann. Rept. for 1905, p. 146, pl. 23, figs. 2, 3; pl. 24, 1906.

aceroides. It is, unfortunately, represented by a scanty amount of material which was collected by C. W. Cooke several years after the remainder of the present report was written.

Occurrence: Ripley formation, roadside 6¾ miles north of Eufala, Barbour County, Ala.

Collection: U. S. National Museum.

Platanus sp.

Plate XXXI, figures 7, 8.

Fragments of what appear to represent a new species of *Platanus* were collected from the lower part of the Ripley formation of eastern Alabama. They are insufficient for proper diagnosis but are included in the present report and figured because plant fossils are so extremely rare in these beds.

Occurrence: Ripley formation, near mouth of Cowikee Creek, Barbour County, Ala.

Collection: U. S. National Museum.

Order PROTEALES.

Family PROTEACEAE.

Genus PROTEOIDES Heer.

Proteoides conospermaefolia Berry, n. sp.

Plate XIV, figure 4.

Leaves narrowly oblanceolate in outline, with a rounded apex and a gradually narrowed, straight margined, extended base. About 8 centimeters in length by 1 centimeter in greatest width, which is in the distal half of the leaf. Midrib stout below, narrow above. Secondaries fine, numerous, diverging from the midrib at angles of over 45°, immersed in the coriaceous leaf substance and indistinct toward the margins along which they arch. Tertiaries fine, mostly obsolete, forming quadrangular or polygonal meshes.

This well-marked new species resembles a number of European Upper Cretaceous species, as, for example, *Euphorbiophyllum antiquum* Saporta and Marion[1] from the Turonian of Bagnols, France. It still more closely resembles certain leaves from the Cenomanian of the island of Lesina, off the Dalmatian coast, which Kerner[2] describes as *Proteoides* cf. *P. grevillaeformis* Heer, although in my judgment they are certainly not to be identified as that species.

The present species is clearly referable to the genus *Proteoides*, by which I mean that it represents an Upper Cretaceous species of the family Proteaceae, whose exact generic relationship is uncertain because of the parallelism in the foliar characters of so many of the genera of this family. The present leaves can be almost exactly duplicated in the existing genus *Conospermum* of the Australian region, and this resemblance has suggested the specific name which has been adopted.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Genus PERSOONIA Swartz.

Persoonia lesquereuxii Knowlton.

Plate XIV, figure 2.

Persoonia lesquereuxii Knowlton, in Lesquereux, The flora of the Dakota group, p. 89, pl. 20, figs. 10–12, 1892.

Newberry, The flora of the Amboy clays, p. 71, pl. 42, fig. 16, 1896; New Jersey Geol. Survey Bull. 3, p. 126, pl. 20, fig. 6, 1911.

Berry, Torrey Bot. Club Bull., vol. 33, p. 173, 1906.

Andromeda latifolia Newberry, The flora of the Amboy clays, p. 120 (part), pl. 33, fig. 9, 1896 (not figs. 6–8, 10).

Leaves obovate in outline, with a broadly rounded apex, subemarginate in one of the specimens from the Dakota sandstone, gradually narrowing to the decurrent base. They range from 1.7 to 5 centimeters in length by 1.2 to 2.5 centimeters in greatest width, which is toward the apex. Petiole stout. Texture subcoriaceous. Secondaries sparse, 3 or 4 pairs, thin, alternate, branching from the stout midrib at an angle of 45° or less, camptodrome.

This species, which was described originally from the Dakota sandstone of Kansas, is somewhat variable in appearance. Hollick referred a small, almost orbicular leaf from the Raritan formation of New Jersey to it, presumably on the basis of its resemblance to Knowlton's figure 12. For the same reason the writer is inclined to think that the form shown in Newberry's Plate XXXIII, figure 9, which he calls an *Andromeda*, is also referable to this species. Similar obovate leaves are also present in the overlying Magothy formation.

As far as I can discover, this species in New Jersey is not found below the upper part of the Raritan.

Occurrence: Tuscaloosa formation, Shirleys Mill, and Glen Allen, Fayette County, Ala.

Collections: U. S. National Museum.

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[1] Saporta, G. de, and Marion, A. F., L'évolution du règne végétal, Phanérogames, vol. 2, p. 117, fig. 125c, 1885.

[2] Kerner, F. von, K.-k. geol. Reichsanstalt Jahrb., Band 45, p. 54, pl. 5, fig. 2, 1896.

Persoonia lesquereuxii minor Berry, n. var.

Plate XIV, figure 3.

Leaves spatulate in outline, somewhat inequilateral, with a rounded apex and decurrent base. Length above 3 centimeters. Maximum width 1.35 centimeters in the upper part of the leaf. Texture coriaceous. Petiole stout, about 7 millimeters in length. Midrib slender, immersed. Secondaries ascending camptodrome, mostly obsolete.

This variety greatly resembles the smaller leaves which are referred to the species, especially those from the Raritan formation of New Jersey, which have been identified by Newberry. The variety is more coriaceous, has more completely immersed venation, and is relatively narrower and more inequilateral in outline. It is considerably smaller than the species as it occurs in the Dakota sandstone of Kansas.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Order RANALES.

Family RANUNCULACEAE (?).

Genus DEWALQUEA Saporta and Marion.

[Acad. roy. sci., lettres et beaux arts Belgique Mém. couronnés et mém. des savants étrangers, vol. 37, p. 55, 1874.]

Dewalquea smithi Berry.

Plate XIV, figure 1; Plate XVI, figures 2, 3.

Dewalquea smithi Berry, Torreya, vol. 10, p. 36, fig. 1, 1910; Torrey Bot. Club Bull., vol. 43, p. 293, 1916.

Leaves palmately decompound, the petiole dividing into three principal branches, the angle of divergence ranging from 20° to 60°, and the two lateral branches forking at an acute angle 1 centimeter to 2 centimeters above their base. The middle leaflet is lanceolate in outline, being widest in its central part and tapering almost equally to the acute apex and base. Length 7.5 to 16 centimeters. Maximum width 1 centimeter to 4 centimeters. Margin entire or serrate, usually entire below and serrate in the apical three-fourths, in some specimens with large aquiline-serrate teeth. Midrib stout. Secondaries regular, subopposite, parallel; about 20 pairs, branching from the midrib at angles ranging from 45° to 70°, usually about 50°, curving upward and running to the marginal teeth, or camptodrome. The base of the leaflet extends downward to a point within 2 or 3 millimeters of the forks of the petiole.

Lateral leaflets, more or less inequilateral, usually somewhat smaller than the middle leaflet. The internal lateral leaflet is lanceolate, the outer lamina starting at or very near the point where the lateral branch of the petiole forks. The inner lamina, however, extends downward almost to the base of the lateral branch, making the base markedly inequilateral. In general outline and marginal and venation characters, it is identical with the middle leaflet. The outer lateral leaflet is also somewhat inequilateral but less so than the internal lateral leaflet, the internal lamina starting at or near the fork and its outer lamina extending more or less below the fork. The marginal and venation characters are like those of the other leaflets.

This handsome species, of which a restoration is shown in figure 11, is abundantly represented in the Middendorf arkose member of the Black Creek formation of South Carolina, mostly by terminal leaflets, a number of which have been figured. It is common in the Tuscaloosa formation at Whites Bluff on the right bank of Black Warrior River, 309 miles above Mobile, Ala. A small collection of fossil plants from this outcrop contained no less than 27 specimens of this form. Several of these specimens were complete and were sketched at the time they were collected, which proved fortunate, for the extremely arenaceous matrix did not withstand shipment very well. The material in the National Museum, although considerably broken, comprises several detached leaflets and three or four basal parts of the leaf, showing the mode of division of the petiole. The species is also represented by detached leaflets at Shirleys Mill in Fayette County.

The genus *Dewalquea* was founded by Saporta and Marion in 1874 upon remains from the Senonian of Westphalia, communicated by Debey and named by him in manuscript *Araliophyllum*, and on additional remains collected by those authors from the Paleocene of Gelinden, Belgium (Marnes heersiennes, étage Thanétien). Three species were enumerated, *Dewalquea haldemiana* and *Dewalquea aquisgranensis* from the Westphalian Senonian, and *Dewalquea gelindenensis* from the basal Eocene. In the past 35 years several additional species have been referred to this genus. These include another species from the German Senonian (*Dewalquea insignis*), described by Hosius and Von der Marck;[1] two species from the Cenomanian of Bohemia (*Dewalquea coriacea* and *Dewalquea pentaphylla*), described by Velenovsky;[2] two American species from the Dakota sandstone (*Dewalquea dakotensis* and *Dewalquea primordialis*), described by Lesquereux,[3] both of which are fragmentary and of uncertain relationship; a species from the Raritan formation of New Jersey (*Dewalquea trifoliata*), described by Newberry;[4] and a species described by Heer[5] from Greenland (*Dewalquea groenlandica*) and subsequently recorded from Staten Island, New Jersey, North Carolina, and Alabama.

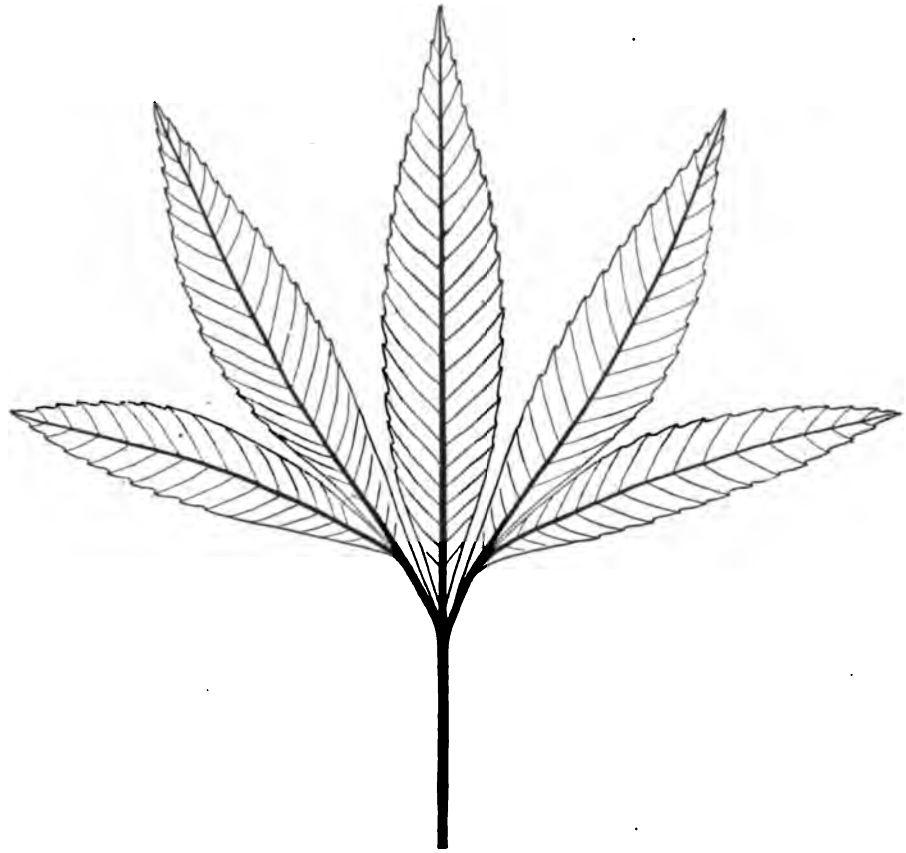

FIGURE 11.—Restoration of *Dewalquea smithi.*

Hosius and Von der Marck[6] record the Eocene species from the Senonian of Westphalia; the remains, however, are not of this species but are fragments of *Dewalquea haldemiana*, which is common at that horizon. The European species *Dewalquea insignia* is recorded by Heer[7] from both the Atane and Patoot beds of Greenland, and by Hollick[8] from the Cretaceous of Staten Island, but both of these determinations are based upon fragments of single leaves and are in my judgment entirely untrustworthy. Attention should also be called to the possibility that *Celastrus arctica* Heer[9] represents the leaflets of a *Dewalquea.* This species was described from the Patoot beds of Greenland, where it is sparsely represented. It is abundant, however, in the upper part of the Raritan formation of New Jersey, but of some scores of specimens examined by the writer all were detached and failed to show their habit of growth.

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[1] Hosius, A., and Von der Marck, W., Palaeontographica, vol. 26, p. 172, pl. 32, figs. 111–113; pl. 33, fig. 109; pl. 34, fig. 110; pl. 35, fig. 123, 1880.

[2] Velenovsky, Josef, Die Flora der böhmischen Kreideformation, vol. 3, p. 11, 14, pl. 1, figs. 1–9, pl. 2, fig. 2, pl. 8.

[3] Lesquereux, Leo, The flora of the Dakota group, p. 211, pl. 59, figs. 5, 6, 1892; Minnesota Geol. and Nat. Hist. Survey, vol. 3, p. 18, pl. A, fig. 10, 1892.

[4] Newberry, J. S., The flora of the Amboy clays; U. S. Geol. Survey Mon. 26, p. 129, pl. 22, figs. 4–7, 1896.

[5] Heer, Oswald, Flora fossilis arctica, vol. 6, pt. 2, p. 87, pl. 29, figs. 18, 19; pl. 42, figs. 5, 6; pl. 44, fig. 11, 1882.

[6] Hosius, A., and Von der Marck, W., op. cit., p. 50.

[7] Heer, Oswald, op. cit., vol. 6, p. 86, pl. 25, fig. 7; pl. 33, figs. 14–16, 1882; idem, vol. 7, p. 37, pl. 58, fig. 3; pl. 62, fig. 7, 1883.

[8] Hollick, Arthur, The Cretaceous flora of southern New York and New England: U. S. Geol. Survey Mon. 50, p. 106, pl. 8, fig. 24, 1907.

[9] Heer, Oswald, op. cit., vol. 7, p. 40, pl. 61, figs. 5d, 5e, 1883.

The botanic relationship of *Dewalquea* has always remained obscure, and there is no better discussion of it than that given by Saporta and Marion,[1] who, after comparing these leaves with those of *Ampelopsis*, *Arisaema*, *Anthurium* (Araceae), Araliaceae, and other forms, arrive at the conclusion that they are prototypes of the tribe Helleboreae of the Ranunculaceae. The claims of the Araliaceae, pointed out by Schenk and others, should not be overlooked in this connection.

The present species is markedly distinct from the American species of *Dewalquea* previously described, all of which were apparently tripartite. Among the European species it is quite similar to the Senonian species *Dewalquea insignis* Hosius and Von der Marck, which is, however, entirely distinct. It is also similar to *Dewalquea coriacea* and *Dewalquea pentaphylla*, which are described by Velenovsky from the Cenomanian of Bohemia.

As mentioned above, this Alabama species shows entire and serrated forms, and it is remarkable that wherever this genus has been found to occur in any abundance, two species are usually described, one entire and one with toothed margins. Thus in Germany *Dewalquea haldemiana* is entire, whereas *Dewalquea insignis* is toothed, though probably both are the leaves of the same plant. In Bohemia *Dewalquea pentaphylla* is entire, whereas *Dewalquea coriacea* is toothed. Both the entire and serrate leaves of the Alabama plant are believed to be specifically identical, as the material shows a great many gradations in the size of the teeth and great variability regarding the proportion which the entire part bears to the toothed part on single leaflets.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; Whites Bluff, Greene County, Ala. Eutaw formation (Coffee sand member), Coffee Bluff, Hardin County, Tenn.

Collections: U. S. National Museum.

Family MAGNOLIACEAE.

Genus MAGNOLIA Linné.

[Species plantarum, p. 535, 1753.]

Magnolia speciosa Heer.

Plate XVIII, figures 3, 4.

Magnolia speciosa Heer, Allg. schweiz. Gesell. gesammt. Naturwiss. Bern Neue Denskchr., Band 23, p. 20, pl. 6, fig. 1; pl. 9, fig. 2; pl. 10, fig. 1, 1869.

Lesquereux, The Cretaceous and Tertiary floras, p. 72, 1874; The flora of the Dakota group, p. 202, pl. 60, figs. 3, 4, 1892.

Hollick, New York Acad. Sci. Trans., vol. 12, p. 234, pl. 7, fig. 4, 1893; Torrey Bot. Club Bull., vol. 21, p. 60, pl. 178, fig. 5, 1894; Geol. Soc. America Bull., vol. 7, p. 13, 1895; The Cretaceous flora of southern New York and New England, p. 64, pl. 19, figs. 1–4, 1906.

Knowlton, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 318, 1901.

Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.

Berry, Torrey Bot. Club Bull., vol. 31, p. 76, pl. 3, fig. 10, 1904; idem, vol. 32, p. 46, pl. 2, figs. 4, 5, 1905; New Jersey Geol. Survey Bull. 3, p. 129, pl. 14, fig. 3, 1911.

Magnolia auriculata Newberry, The flora of the Amboy clays, p. 75 (part), pl. 41, fig. 13; pl. 58, fig. 10, 1896.

Heer's description, published in 1869, is as follows:

> M. foliis maximis, coriaceis, ovato-ellipticis, apice longe attenuatis, valde acuminatis, basi in petiolum validum attenuatis, nervo primario crasso, nervis secundariis valde curvatis, camptodromis.

This species is somewhat variable in size. The American material, which is somewhat smaller than the type material from Moletein, Moravia, ranges in length from 8.5 to 19 centimeters and in maximum width from 4 to 7.5 centimeters. It is ovate-elliptical in outline, with the apex more or less produced and the base decurrent. The midrib and petiole are stout. The secondaries are well marked, camptodrome; they number seven to nine pairs and are subopposite, branching from the midrib at angles of about 45° and curving upward. The texture is coriaceous.

This species, which was described originally from the Cenomanian of Moravia, has been found to have a wide range in America. Typical leaves occur in the Dakota sandstone and also as far south as Texas. It is present on Marthas Vineyard and Long Island and in the Magothy formation of New Jersey. Though not heretofore reported from the Raritan formation, it would seem as if some of the leaves which Prof. Newberry described as *Magnolia auriculata* should be referred to this species. They range down in size, but this is also true of some of the western leaves of this species. *Magnolia auriculata* was reported by Ward from the Tuscaloosa formation of Alabama, but all of the specimens so labeled which have come into the writer's hands for study are closer to *M. speciosa*, and not one shows any tendency toward an auriculate base, which is the main characteristic of *M. auriculata*. This may of course have been a variable feature, as it is to a certain extent in the existing *M. fraseri* Walter and *M. macrophyllia* Michaux, but if it is worth anything at all in the fossils it is worth emphasizing.

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[1] Saporta, G. de, and Marion, A. F., L'évolution du règne végétal, Phanérogames, vol. 2, pp. 55–61, 1885.

Magnolia speciosa is common in the lower part of the Tuscaloosa formation and is the most abundant form at the Cottondale locality. It has not been discovered in the upper part of the Tuscaloosa or in the Eutaw formation.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, Fayette County; Cottondale, and gully at Tuscaloosa, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Magnolia capellinii Heer.

Plate XVIII, figure 1; Plate XXXII, figure 7.

Magnolia capellinii Heer, Phyllites crétacées du Nebraska, p. 21, pl. 3, figs. 5, 6, 1866; Flora fossilis arctica, vol. 3, Abt. 2, p. 115, pl. 33, figs. 1–4, 1874; idem, vol. 6, Abt. 2, p. 90, pl. 24, figs. 3–5, pl. 25, figs. 1–3, pl. 45, fig. 1, 1882.

Velenovsky, Die Flora der böhmischen Kreideformation, pt. 2, p. 20, pl. 7, figs. 8, 9, 1883.

Lesquereux, The flora of the Dakota group, p. 203, pl. 46, fig. 1, 1892.

Dawson, Roy. Soc. Canada Trans., 1st ser., vol. 11, sec. 4, p. 63, pl. 11, fig. 49; pl. 13, fig. 49a, 1894.

Hollick, New York Acad. Sci. Trans., vol. 12, p. 234, pl. 6, fig. 6, 1893; New York Bot. Garden Bull., vol. 3, p. 413, pl. 78, fig. 3, 1904; The Cretaceous flora of southern New York and New England, p. 63, pl. 17, figs. 3, 4, 1907.

Berry, Torrey Bot. Club Bull., vol. 31, p. 76, pl. 3, fig. 3, 1904; New Jersey Geol. Survey Ann. Rept. for 1905, p. 138, 1906; Torrey Bot. Club Bull., vol. 34, p. 195, pl. 12, figs. 4, 5, 1907.

Magnolia sp. Berry, Johns Hopkins Univ. Circ., new ser., No. 7, p. 81, 1907.

The leaves of this species vary considerably in size, averaging about 13 centimeters in length by 7 centimeters in maximum width. Outline broadly ovate, the base and apex usually about equally pointed, although a few specimens have a somewhat obtuse apex, whereas others have it extended, as it is in some of the material from North Carolina and in the fragments identified as this species from South Carolina. Texture coriaceous or subcoriaceous. Midrib and petiole stout. Secondaries usually seven or eight alternate or subopposite pairs at regular intervals, approximately parallel, camptodrome.

This widespread species in some of its forms approaches quite close to the less narrow and less apically extended form of *Magnolia speciosa* Heer. Ordinarily, however, *Magnolia speciosa* may be readily distinguished by its relatively narrower form, with the produced tip and decurrent base. *Magnolia capellinii* was described originally from the Dakota sandstone by Heer and has been collected from a large number of localities of homotaxial age, from eastern Europe, Greenland, and the Pacific coast of North America. In the Atlantic Coastal Plain it characterizes the Magothy formation of the northern slope and is present in the Black Creek formation of North Carolina, the Middendorf arkose member of the Black Creek formation of South Carolina, and the Tuscaloosa formation of Georgia and Alabama. In Alabama it is only known from the single locality cited, where it is not abundant and may be simply a variant of *Magnolia speciosa*, which is so very common at that locality. A slightly variant form occurs in the Ripley formation of western Tennessee.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala. Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga. Ripley formation (McNairy sand member), 2½ miles southwest of Selmer, McNairy County, Tenn.

Collections: U. S. National Museum.

Magnolia newberryi Berry.

Plate XX, figure 4.

Magnolia newberryi Berry, Torrey Bot. Club Bull., vol. 34, p. 195, pl. 13, fig. 6, 1907; New Jersey Geol. Survey Bull. 3, p. 133, pl. 13, 1911.

Magnolia longifolia Hollick, New York Acad. Sci. Trans., vol. 12, p. 36, pl. 3, fig. 9, 1892; New York Acad. Sci. Ann., vol. 11, p. 422, pl. 37, fig. 3, 1898; The Cretaceous flora of southern New York and New England, p. 66, pl. 20, figs. 2, 3 (not Sweet, 1826), 1906.

Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.

Newberry, The flora of the Amboy clays, p. 76, pl. 55, figs. 3, 5; pl. 56, figs. 1-4.

Leaves mostly of large size, ovate to oblong in outline, about 20 centimeters in length by 9 to 10 centimeters in maximum width, broadest toward the base. Apex subacute or obtuse. Base varying from obtusely rounded, almost truncate, to somewhat cuneate. Petiole and midrib stout. Secondaries comparatively thin and open, about 12 pairs, camptodrome. Tertiaries forming 4, 5, or 6 sided areoles, prominent in some specimens.

This is the largest fossil *Magnolia* of the Coastal Plain, and some of its leaves are said by Newberry to reach a length of 30 centimeters or more. In a general way it resembles an immense leaf of *Magnolia woodbridgensis*, and it also approaches somewhat *Magnolia longipes*, but the petiole is only about one-third the length of that of the latter species. It is common in the middle part of the Raritan formation of New Jersey through the Black Creek formation in North Carolina and is present at various points along the Atlantic Coastal Plain. It is present in the lower part of the Tuscaloosa formation in western Alabama, but owing to its large size it has generally become more or less broken before fossilization.

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County, Ala.

Collections: U. S. National Museum.

Magnolia obtusata Heer.

Plate XVII, figures 7, 8.

Magnolia obtusata Heer, Flora fossilis arctica, vol. 6, Abt. 2, p. 90, pl. 15, fig. 12, pl. 21, fig. 3, 1882.

Lesquereux, The flora of the Dakota group, p. 201, pl. 60, figs. 5, 6, 1892.

Berry, New York Bot. Garden Bull., vol. 3, p. 76, pl. 47, fig. 4, 1903; Torrey Bot. Club Bull., vol. 37, p. 23, 1910.

Magnolia capellinii Heer, Flora fossilis arctica, vol. 3, Abt. 2, pl. 33, fig. 4, 1874 (no other citations of this species).

Leaves of variable size, oblong ovate or obovate in outline, entire, with a broadly rounded apex and a narrowed cuneate base, ranging from 7 to 14 centimeters in length by 2.4 to 7 centimeters in greatest width, which is above the middle. Petiole and midrib stout. Secondaries few in number ascending, curved, camptodrome. Texture coriaceous.

This species was described from the Atane beds of Greenland by Heer and was based upon rather fragmentary material. Subsequently Lesquereux recorded some fine specimens from the Dakota sandstone of Kansas. It is present in the Magothy formation from New Jersey to Maryland, and in beds of homotaxial age in South Carolina. In western Alabama it appears to be confined to the lower part of the Tuscaloosa formation of Fayette County.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Magnolia boulayana Lesquereux.

Plate XVIII, figure 2.

Magnolia boulayana Lesquereux, The flora of the Dakota group, p. 202, pl. 60, fig. 2, 1892.

Magnolia glaucoides Hollick, Torrey Bot. Club Bull., vol. 21, p. 60, pl. 175, figs. 1, 7, 1894.

Magnolia glaucoides Hollick. Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.

Magnolia glaucoides Newberry, The flora of the Amboy clays, p. 74, pl. 57, figs. 1-4, 1896.

Magnolia boulayana Lesquereux. Knowlton, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 318, 1901.

Magnolia glaucoides Hollick, The Cretaceous flora of southern New York and New England, p. 67, pl. 19, fig. 6; pl. 20, fig. 6, 1906.

Magnolia boulayana Lesquereux. Berry, Torrey Bot. Club Bull., vol. 36, p. 254, 1909; idem, vol. 37, p. 23, 1910.

New Jersey Geol. Survey Bull. 3, p. 131, pl. 14, fig. 2, 1911.

Leaves narrowly elliptical in outline, unusually uniform in size and shape, 8.5 to 13 centimeters in length and 3.5 to 4.5 centimeters in maximum width. Apex usually bluntly rounded, in some specimens acute. Base matching the apex. Petiole rather stout, 3 to 4 centimeters in length. Midrib rather stout. Secondaries slender, commonly obsolete, about 11 pairs, equidistant, parallel, camptodrome, branching from the midrib at an angle of about 40°. Tertiaries, when seen, transverse. Texture coriaceous.

This species was described originally from the Dakota sandstone of Kansas by Lesquereux. Newberry described the Raritan remains, which are abundant at the Woodbridge locality, as a new species and it has been kept distinct by Hollick, who recognized, however, its practical identity with the Dakota sandstone plant. There can be no question but that they belong to the same species, and it seems probable that *Magnolia vaningeni* described by Hollick[1] should also be referred to the same species.

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[1] Hollick, Arthur, Torrey Bot. Club Bull., vol. 21, p. 61, pl. 175, fig. 6, 1894.

In addition to the localities already mentioned this species is found on Marthas Vineyard and Long Island, in the Eutaw formation of western Georgia, and in the Woodbine sand of the western Gulf region (Texas). Characteristic specimens of this species are present in the lower beds of the Tuscaloosa formation of Fayette County, Ala.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala. Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga.

Collections: U. S. National Museum.

Magnolia longipes Hollick.

Magnolia longipes Hollick, Torrey Bot. Club Bull., vol. 21, p. 60, pl. 178, fig. 3, 1894.
Newberry, The flora of the Amboy clays, p. 76, pl. 54, figs. 1-3, 1896.
(?) Hollick, The Cretaceous flora of southern New York and New England, p. 64, pl. 21, figs. 5, 6, 1906.
Berry, Torrey Bot. Club Bull., vol. 37, p. 23, 1910; New Jersey Geol. Survey Bull. 3, p. 135, pl. 14, fig. 1, 1911.
Magnolia alternans Heer. Ward, in Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894 (not Heer).

Leaves oblong-ovate in outline, apparently about 18 centimeters in length by 6 to 7 centimeters in maximum width, which was below the middle. Apex obtusely rounded. Base usually cuneate. Midrib and petiole very stout, the latter unusually long, reaching 12 to 13 centimeters in some specimens. Secondaries camptodrome, relatively thin and remote, 10 to 12 pairs, branching from the midrib at angles of about 45° and curving upward in a short distance to join a branch from the secondary next above. The secondaries thus form a series of large arches which approximately parallel the margin and constitute one of the distinctive characters of this species, another being the long petiole and the oblong, almost straight-sided shape.

This leaf is a very striking *Magnolia* and is common in the middle part of the Raritan formation at Woodbridge, N. J. Fragmentary specimens which have been correlated with these remains are reported from Long Island. It is apparently quite different in appearance from any of the other Cretaceous species of *Magnolia*, although it suggests somewhat a gigantic form of *Magnolia woodbridgensis*. It is found in the Magothy formation of Maryland. The occurrence in Alabama is based upon the material from the Cottondale locality, which is more or less fragmentary and similar to that identified as *Magnolia alternans* Heer by Ward. In the absence of complete specimens, only the basal part as a rule being preserved, it is quite possible that the present specimens are not distinct from *Magnolia speciosa*, which is so abundant at this locality.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County; Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Magnolia lacoeana Lesquereux.

Plate XVII, figure 9

Magnolia lacoeana Lesquereux, The flora of the Dakota group, p. 201, pl. 60, fig. 1, 1892.
Newberry, The flora of the Amboy clays, p. 73, pl. 55, figs. 1, 2, 1896.
Hollick, The Cretaceous flora of southern New York and New England, p. 65, pl. 17, fig. 2, 1906.
Berry, Torrey Bot. Club Bull., vol. 37, p. 23, 1910; New Jersey Geol. Survey Bull. 3, p. 134, pl. 16, fig. 2, 1911.

Leaves broadly oval to almost orbicular in outline, obtuse or abruptly pointed above and rounded to a somewhat cuneate base below, 10 to 12 centimeters in length by 8.5 to 9.5 centimeters in maximum width. Midrib stout, somewhat flexuous. Secondaries numerous, camptodrome, rather stout, 10 to 12 pairs; they branch from the midrib at acute angles, immediately curving outward, forming festoons near the margin, which is somewhat undulate in one specimen that Newberry referred to this species.

This species differs from its contemporaries, especially in its nearly round outline; Lesquereux finds a resemblance to *Magnolia inglefieldi* Heer from Greenland, and it also suggests some of the Arctic forms which have been referred to *Magnolia capellinii* Heer.

Although this species is reported from such widely separated points as Marthas Vineyard and Kansas, it is nowhere abundant and is usually poorly preserved, suggesting that the leaves were readily macerated. It also occurs in unreported collections from the Magothy formation in Maryland. In Alabama it appears to be confined to the lower part of the Tuscaloosa formation of Fayette County.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, Fayette County, Ala.

Collections: U. S. National Museum.

Magnolia hollicki Berry.

Magnolia hollicki Berry, Torrey Bot. Club Bull., vol. 36, p. 253, 1909; New Jersey Geol. Survey Bull. 3, p. 136, pl. 15, fig. 3, 1911.

Magnolia auriculata Hollick, Torrey Bot. Club Bull., vol. 21, p. 61, pl. 179, figs. 6, 7, 1894; The Cretaceous flora of southern New York and New England, p. 67, pl. 19, fig. 5; pl. 20, figs. 5, 8, 1906 (not Lamarck, 1783).

Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.

Newberry, The flora of the Amboy clays, p. 75, pl. 58, figs. 1-9, 11, 1896 (not fig. 10).

Berry, Torrey Bot. Club Bull., vol. 33, p. 174, 1906.

Dicotyledonous leaf impression, Hitchcock, Final report on the geology of Massachusetts, vol. 2, p. 430, pl. 19, fig. 1 (part), 1841.

Leaves orbicular-ovate in outline, 4 to 10 centimeters in length by 2 to 5.5 centimeters in width, petiolate. Apex acute, slightly extended in one or two specimens. Base usually pronouncedly auriculate. Petiole and midrib stout. Secondaries few, 6 or 7 pairs subopposite, camptodrome. Texture smooth and subcoriaceous.

This magnificent species is abundant and well preserved at Woodbridge, N. J., in the Raritan formation, on Marthas Vineyard, and in the Magothy formation of Maryland. Newberry was somewhat uncertain as to its relationship with *Magnolia* and compared it with *Aristolochia*, *Polygonum*, and *Toxylon*. Of these genera *Toxylon* is the only one which is at all suggestive, and none of its species has the auriculate base, whereas this character of base prevails in more than one modern species of *Magnolia*. The outline, consistency and venation, are all in accord in pointing to *Magnolia* as the proper generic reference. This form is one of those mentioned from Marthas Vineyard by Hitchcock.[1]

Ward identified this species from Cottondale, Shirleys Mill, and Glen Allen, in Alabama, but in restudying these collections I have referred these forms to *Magnolia speciosa* Heer and confined *M. hollicki* to forms with an auriculate base. I have seen only a single specimen of *M. hollicki*, which is, however, typical, being an almost exact counterpart of Newberry's figure 11 in size and outline, differing merely in the more pronounced basal auricles of the Tuscaloosa specimen.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Genus LIRIODENDRON Linné.

Liriodendron meekii Heer.

Plate XX, figure 2.

Liriodendron meekii Heer, in Meek and Hayden, Acad. Nat. Sci. Philadelphia Proc., vol. 10, p. 265, 1858.

Heer, Phyllites crétacées du Nebraska, p. 21, pl. 4, figs. 3, 4, 1866.

Newberry, Illustrations of Cretaceous and Tertiary plants, pl. 6, figs. 5, 6, 1878.

Lesquereux, The flora of the Dakota group, p. 205, pl. 28, figs. 5, 6, 1892.

Engelhardt, Naturwiss. Gesell. Isis in Dresden Abh. 7, Jahrg. 1891, p. 100, 1892 (?).

Kurtz, Rev. Mus. La Plata, vol. 10, p. 53, 1902 (?).

Liriodendron meekii genuina Heer, Flora fossilis arctica, vol. 6, Abt. 2, p. 89, pl. 22, figs. 12, 13; pl. 23, fig. 6, 1882.

Liriodendron primaevum Newberry, Lyceum Nat. Hist. New York City Ann., vol. 9, p. 12 (part), 1868.

Newberry, Illustrations of Cretaceous and Tertiary plants, pl. 6, fig. 7, 1878 (misnumbered as fig. 6).

Lesquereux, The flora of the Dakota group, p. 203 (part), pl. 26, fig. 2, 1892.

Newberry, The later extinct floras of North America, p. 96, pl. 6, fig. 7, 1898.

Hollick, New York Acad. Sci. Trans., vol. 12, p. 8, pl. 3, fig. 4, 1892.

Hollick, The Cretaceous flora of southern New York and New England, p. 68, pl. 21, fig. 7, 1906.

Liriodendron meekii primaeva Heer, Flora fossilis arctica, vol. 6, Abt. 2, p. 88 (part), pl. 23, fig. 5, 1882.

Leaves of relatively small size, more or less panduriform in outline; described by Newberry as three-lobed with the median lobe emarginate. Length along the midrib 5 to 10 centimeters, usually about 5 centimeters, the specimen from Alabama being 4.7 centimeters. Greatest width, which is toward the base of the leaf, 2.4 to 7 centimeters, averaging about 4 centimeters, the specimen from Alabama being 4.3 centimeters. Lobes more or less well marked, the basal pair directed laterally and broadly rounded, the upper pair directed diagonally, usually less well marked, rounded at the outside and inclined toward angularity at the tip. Lateral sinuses more or less indented in the typical forms, such as the specimen figured from Alabama, extending nearly halfway to the midrib and broadly rounded. Apical sinus wide and open, usually cuneate in outline. Base somewhat descending close to the midrib, broadly and somewhat curved cuneate. Midrib stout, straight, or somewhat curved. Secondaries thin, parallel, about six pairs, branching from the midrib at angles of over 45° and gently curving upward toward their extremities, probably camptodrome, their ultimate course not made out.

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[1] Hitchcock, Edward, Final report on the geology of Massachusetts, vol. 2, p. 430, 1841.

The middle Cretaceous leaves variously described as *Liriodendron meekii*, *L. primaevum*, *L. semialatum*, and *L. simplex* are in a state of almost hopeless confusion, owing largely to the difficulty of determining the specific lines of cleavage in a probably genetic and variable series of forms.

Liriodendron meekii, from the Dakota sandstone of Nebraska, was described by Heer in 1858, in an appendix to a paper by Meek and Hayden. It was described as trilobate and was not figured, but was compared with the European *Liriodendron procaccinii* Unger and with the living *Liriodendron tulipifera* Linné. In 1866 the same author returned to this subject and gives figures of the two well-known specimens, which have been reproduced by both Lesquereux and Newberry. It would seem that this form must be considered as the type of this species and the present writer so considers it. However, Heer in describing the Atane flora of Greenland in 1882, returned to this subject and considered this form, as well as various simple emarginate *Liriodendropsis*-like forms, as different varieties of *Liriodendron meekii*. In this treatment he was subsequently followed by Lesquereux, but not by Newberry, who insisted upon the distinctness of the lobate form. We find one of Heer's varieties, *Liriodendron meekii genuina*, which may belong here, although the leaves are exceptionally large and poorly preserved. Another variety, *Liriodendron meekii primaeva*, includes the slightly lobate forms subsequently referred to *Liriodendron primaevum* Newberry. It is apparently the latter which Engelhardt reports from the Cenomanian of Saxony. It would seem that the small entire retuse leaves which have been variously referred to *Leguminosites*, *Bumelia*, *Bignonia*, *Liriodendron meekii*, and *L. primaevum*, as well as to *L. simplex* and to the genus *Liriodendropsis*, are more probably allied to the Leguminosae than to *Liriodendron*, and they are so considered in the present study. On the other hand, *Liriodendron meekii* is restricted to include only such lobate forms as do not seem to be specifically distinct from the originally figured types, and with them are merged those forms usually referred to *Liriodendron primaevum* Newberry, which are simply variants of the type just mentioned with less prominently developed lobes.

As here delimited, the species is found in the Dakota sandstone; in morainic material on Staten Island, derived from the Raritan formation, or possibly from the Magothy formation; somewhat doubtfully in the Atane beds of Greenland; doubtfully in the lower part of the Black Creek formation of North Carolina;[1] positively in the lower part of the Tuscaloosa formation in Alabama; and doubtfully in the South American Cretaceous and in the Cenomanian of Saxony.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Family MENISPERMACEAE.

Genus COCCULUS De Candolle.

Cocculus cinnamomeus Velenovsky (?).

Plate XVII, figure 1.

Cocculus cinnamomeus Velenovsky, Die Flora der Böhmischen Kreideformation, pt. 4, p. 65(4), pl. 8 (31), figs. 16–21, 1885.

Hollick, The Cretaceous flora of southern New York and New England, p. 62, pl. 12, figs. 10–12, 1906.

Leaves small, ovate in outline, with acute base and apex, triveined from a point at or near the base. Primaries acrodrome. Margins entire. Very close to the existing *Cocculus laurifolius* De Candolle.

The Alabama material, which is fragmentary, denotes a smaller leaf than the type, which is from the Cenomanian of Bohemia. It is, however, unquestionably identical with the leaves from Marthas Vineyard which Hollick identifies as this species. As the grounds for this long-range identification are more or less insecure the occurrence of this species in Alabama is queried. The modern species of *Cocculus* number about thirty and are massed in the oriental Tropics, although several are known from the Western Hemisphere.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

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[1] Berry, E. W., Torrey Bot. Club Bull., vol. 34, p. 197, 1907.

Cocculus polycarpaefolius Berry, n. sp.

Plate XVII, figures 2, 3.

Leaves of relatively medium size, elliptic-acuminate in outline, with a short acuminate apex, full rounded sides, and broad, at length decurrent base. Length 4 to 6 centimeters. Maximum width 2 to 4 centimeters in the basal half of the leaf. Primaries three, thin, acrodrome from the base, of equal caliber. Angle of divergence between the laterals and the midrib acute, about 20° or less. The laterals give off two or three curved camptodrome secondaries on the outside, and in some specimens the lower, which diverges at an acute angle, bends upward and pursues an acrodrome course, parallel with the margin, precluding the development of distal lateral secondaries. Tertiaries thin, obliquely transverse.

The present species, which is an obviously new element in our eastern Cretaceous floras, is named in allusion to its resemblance to *Cocculus polycarpus* Roxburg from India. It is readily distinguishable from the associated Tuscaloosa species of *Cocculus*.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Cocculus problematicus Berry, n. sp.

Plate XVII, figure 4.

Leaves oblong-linear in outline, 9 to 10 centimeters in length, by about 2 centimeters in maximum width. Apex obtusely pointed. Base broadly rounded, slightly decurrent at the short, stout, curved petiole. Margins entire. Venation acrodrome from the base. Midrib stout. Lateral primaries thin, two on each side branching from the extreme base, the outer forming a thin, more or less arching, marginal hem, the inner 1 millimeter to 2 millimeters inside the outer and somewhat more prominent, connected with the midrib by oblique transverse tertiaries.

This species is unique in character and of rather uncertain botanic affinity. It is more elongated and linear than *Cocculus cinnamomeus* Velenovsky, although it resembles somewhat some of the forms from Marthas Vineyard which Hollick refers to this species.[1] They differ in their greater elongation, less ovate outline, and broader base.

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County, Ala.

Collections: U. S. National Museum.

Genus MENISPERMITES Lesquereux.

Menispermites integrifolius Berry, n. sp.

Plate XX, figure 1.

Leaves deltoid-ovate in outline, with a short, sharply pointed apex and a truncate or slightly cordate, peltate base. Length about 6.5 centimeters. Maximum width, in the basal part of the leaf, about 6.5 centimeters. Margins entire, full and rounded. Texture subcoriaceous. Petiole missing. Midrib stout, enlarged proximad. Lateral primaries subopposite, suprabasilar, only slightly differentiated from true secondaries, of which they constitute the second pair. They diverge from the midrib at angles of about 45° or slightly more, and are relatively straight for more than half the distance to the margin, then curve upward and are eventually camptodrome. Secondaries well marked, four or five opposite to alternate pairs, irregularly spaced, one pair below the primaries, all camptodrome. Primaries give off on their outer sides three to five curved camptodrome laterals. Tertiaries thin, percurrent, with a few laterals from midrib parallel with secondaries.

This species is not at all trilobate, as are some of the species from the Dakota sandstone from which it also differs in having camptodrome instead of craspedodrome lateral primaries. Among described forms it is like some of the leaves from the Raritan formation of New Jersey that Newberry referred to *Menispermites borealis* Heer, without greatly resembling the type material of that species. The most similar figured form is one given by Newberry,[2] which differs from the present species in its inequilateral form. Superficially *Menispermites integrifolius* suggests the associated *Cordia apiculata* (Hollick) Berry, differing especially in its peltate base. It may also be compared with different Upper Cretaceous leaves that have been commonly referred to *Populus*, some of which have been referred by various students to *Cocculus*. The fossil seems to resemble

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[1] Hollick, Arthur, U. S. Geol. Survey Mon. 50, pl. 12, fig. 13, 1907.

[2] Newberry, J. S., The flora of the Amboy clays: U. S. Geol. Survey Mon. 26, pl. 50, fig. 2, 1895.

Cocculus more closely, but in view of the uncertainty of such a reference *Menispermites* will serve equally well as a generic designation for leaves of the family *Menispermaceae.*

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Menispermites trilobatus Berry, n. sp.

Plate XVII, figures 5, 6.

Leaves of relatively small size, elliptical in general outline, trilobate, 3.5 to 5 centimeters in length by 4 to 6 centimeters in maximum width, which is from tip to tip of the lateral lobes. Petiole stout, about 1.5 centimeters in length. Margins entire, slightly repand in places. Apex broadly rounded, in some specimens retuse mucronate. Base very broadly rounded, more or less peltate. Apical lobe wide and rounded, lateral sinuses very open and shallow, extending inward not more than one-seventh of the distance to the base, broadly rounded. Lateral lobes directed at angles of 45° to 55° with the midrib, with rounded tips, which are somewhat narrower than that of the median lobe; the position of the tips of the lateral lobes is about half the distance between the apex and the base of the leaf, or somewhat less. From this point the margin curves downward in a full lunate curve that is not broken for the attachment of the petiole, which is within the margin a distance of several millimeters.

Midrib rather stout from the peltate base. Lateral primaries of about the same caliber diverge from the extreme base at angles of 45° to 55° and run to the tips of the lateral lobes in an almost straight course. The lateral primaries, as well as the midrib, give off several pairs of secondaries, at angles somewhat in excess of 45°, which are curved and ultimately camptodrome. Marginal tertiaries form small arches within the margin and more or less open pentagonal and inequilateral meshes within the secondaries.

This fine species is entirely distinct from any previously described forms and is clearly referable to the genus *Menispermites* and genetically related to the modern Menispermaceae. *Menispermites* is an abundant type and is especially well represented in the flora of the Dakota sandstone, the present species suggesting a close relationship with *Menispermites grandis* Lesquereux [1] and *M. obtusilobus* Lesquereux [2] of that formation. Curiously enough Kurtz[3] has recorded *M. obtusilobus* from the Upper Cretaceous of Argentina in southern South America, but as he has failed to publish figures of any of his forms their identification can not be considered to be above suspicion. The Tuscaloosa species resembles a small leaf of *Aspidiophyllum trilobatum* Lesquereux[4] of the Dakota sandstone, differing somewhat in the character of the base.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Menispermites variabilis Berry.

Menispermites variabilis Berry, U. S. Geol. Survey Prof. Paper 84, p. 113, pl. 21, figs. 1–4, 1914.

This species was recently described by me from the eastern Gulf area in the publication cited and the discussion need not be repeated here.

Occurrence: Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga.

Collection: U. S. National Museum.

Order PAPAVERALES.

Family CAPPARIDACEAE.

Genus CAPPARITES Berry, n. gen.

Relatively large, orbicular or elliptical, more or less retuse, pinnately veined, petiolate, entire margined, leaves of the general character of those of the modern genus *Capparis* of Linné.

Capparites cynophylloides Berry, n. sp.

Plate XXII, figure 1.

Leaves of relatively large size and variable form, ranging in outline from elliptical to deeply retusely obovate. Length ranging from 6 to 8 centimeters. Maximum width 4.75 to 7 centimeters in the middle part of the leaf. Margins entire, more or less repand, full, reflected in apical part of leaf to form a retuse sinus with a maximum depth of 1.5 centimeters. Petiole stout, about 2.5 centimeters in length.

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[1] Lesquereux, Leo, The Cretaceous and Tertiary floras, p. 80, pl. 15, figs. 1, 2, 1883.

[2] Lesquereux, Leo, The Cretaceous flora, p. 94, pl. 25, figs. 1, 2; pl. 26, fig. 3, 1874.

[3] Kurtz, Federico, Rev. Mus. La Plata, vol. 10, p. 53, 1902.

[4] Lesquereux, Leo, The Cretaceous and Tertiary floras, p. 87, pl. 12, fig. 1; pl. 13, figs. 1-5: pl. 14, fig. 1, 1883.

Midrib stout, usually curved. Secondaries relatively thin, five to seven opposite to alternate pairs, branching from midrib at angles of 45° or more, somewhat irregular in both their spacing and course, ultimately camptodrome. Texture coriaceous.

This species varies from the equilateral almost obcordate leaf figured to the inequilateral elliptical form also figured. Among modern species it is so close to *Capparis cynophallophora* Linné, a West Indian species, that the genus has been named *Capparites*. The modern genus *Capparis* Linné includes over a hundred species of trees the majority of which inhabit Central America and northern South America, although it is also present in the Tropics of the Old World.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala. (Collected by E. W. Berry.)

Collection: U. S. National Museum.

Capparites orbiculatus Berry, n. sp.

Plate XXII, figures 2, 3.

Leaves somewhat smaller than in the preceding species, nearly orbicular in general outline, about 5 to 6 centimeters in longitudinal and lateral diameter. Margin entire, slightly repand. Texture subcoriaceous. Petiole missing but apparently present, as shown by the character of the broken base in the figured specimen. Midrib thinner than in *Capparites cynophylloides* Berry, decidedly flexuous. Secondaries thin, four or five subopposite to alternate pairs, branching from the midrib at angles of 45° or more, curving upward, camptodrome. Tertiaries consisting of camptodrome veins in marginal region and percurrent veins internally. In the lower marginal region there are three or four camptodrome tertiaries from the outside of the basal secondaries, and one or two nearly horizontal camptodrome pseudosecondaries from the midrib on either side, below the lowest true secondaries.

The present species, which is not common, is similar to some of the forms assumed by the existing *Capparis cynophallophora* Linné as well as to other tropical American species of *Capparis*, and it may be only a variety of *C. cynophylloides*, especially as it occurs at the same outcrop.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala. (Collected by E. W. Berry.)

Collection: U. S. National Museum.

Order ROSALES.

Family MIMOSACEAE.

Genus INGA Willdenow.

Inga cretacea Lesquereux.

Plate XXII, figures 4, 5.

Inga cretacea Lesquereux, The flora of the Dakota group, p. 153, pl. 55, fig. 11, 1892.
Bartsch, Iowa Univ. Lab. Nat. Hist. Bull., vol. 3, p. 181, 1896.
Knowlton, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 318, 1901.

Leaves narrowly oblong-lanceolate in outline, usually inequilateral, about 9 centimeters in length by about 2 centimeters in maximum width, which is below the middle. They taper downward from this point to the cuneate and slightly decurrent base and upward to the acuminate tip, which in a measure suggests a small leaf of *Ficus daphnogenoides*, as may be seen by comparing the present species with figures of some of the specimens of that species from Alabama. Petiole short and thick, about 1 centimeter in length. Midrib stout below and curved, becoming thin distad. Secondaries numerous, about 14 opposite or subopposite pairs, branching from the midrib at acute angles of about 30°, camptodrome.

This species was described by Lesquereux from the Dakota sandstone of Kansas. It has been recorded by Bartsch from this same formation in Iowa, and by Knowlton from the Woodbine sand of Texas. The present is the first recorded occurrence of this species east of Mississippi River. It may be compared with many described species of *Leguminosites* and also to a lesser extent with numerous European Tertiary species referred to *Cassia*. Lesquereux called attention to its resemblance to the European Tertiary *Inga icari* Unger,[1] and to the living *Inga semialata* Martius of tropical Brazil.

The writer has collected leaves of the *Inga* type not greatly different from the present species from both the lower Eocene (Wilcox group) and the middle Eocene (Claiborne group) of the Mississippi embayment region.

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[1] Unger, Franz, Die fossile Flora von Kumi auf der Insel Euboea, p. 87, pl. 16, fig. 10, 1867.

The modern species of *Inga* are numerous, more than 150 being known. These species inhabit the American tropics, extending southward into the subtropical region of South America but not reaching northward as far as the United States.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Family CAESALPINIACEAE.

Genus HYMENAEA Linné.

[Species plantarum, p. 1192, 1753.]

Hymenaea fayettensis Berry, n. sp.

Plate XXIII, figure 2.

Leaves with a short, stout petiole; compound; consisting of two ovate-lanceolate, entire margined leaflets. Leaflets sessile with a markedly inequilateral, cuneate or slightly decurrent base but not noticeably inequilateral above the base; 6.5 to 8 centimeters in length, by 2 to 3 centimeters in maximum width, which is in the lower half of the leaflets; tips extended, acuminate. Midribs stout below, becoming thin above. Secondaries thin, camptodrome, numerous, seven or eight subopposite to alternate pairs in each leaflet; they branch from the midrib at angles ranging from 30° to 50° and curve upward, the lower being quite ascending and the angle of divergence becoming progressively greater toward the apex of the leaflets. Tertiaries numerous, very fine, transverse. Texture less coriaceous than in most of the recent species.

This form is a well-defined species of this interesting genus of the Caesalpiniaceae and is quite distinct from any of those previously described. Although the genus *Hymenaea* is confined to tropical America in the existing flora, it seems to have been cosmopolitan in the late Mesozoic, several well-characterized species having been described from the Upper Cretaceous of this country and Europe. The present species is most like *Hymenaea primigenia* Saporta, a species described by Saporta [1] and Velenovsky [2] from the Cenomanian of Bohemia and recorded by Hollick [3] from the Magothy formation on Marthas Vineyard. In this form the leaflets are petiolate, and the margins are commonly crenate-dentate. The other known American Cretaceous species is *Hymenaea dakotana* described by Lesquereux [4] from the Dakota sandstone of Kansas, and recorded by Newberry [5] from the Raritan formation (probably upper Raritan) of New Jersey, by Hollick [6] from Long Island and Marthas Vineyard, and by me[7] from the Magothy formation of New Jersey.

This widespread species is not unlike the present species in some specimens, but in general the leaflets are much smaller and more inequilateral, with shorter tips and with petiolules of considerable length. The two species are perfectly distinct.

The curious bifoliolate leaf habit which characterizes *Hymenaea* is not confined to that genus but is shared by other genera of the Caesalpiniaceae and Mimosaceae, as, for example, by certain species of *Bauhinia*, *Leucaena*, *Cassia*, *Acacia*, *Cynometra*, and *Inga*. Usually, however, the general habit, shape, venation characters, and other features enable the student to distinguish between them.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Genus BAUHINIA Linné.

[Species plantarum, p. 374, 1753.]

Bauhinia cretacea Newberry.

Bauhinia cretacea Newberry, Torrey Bot. Club Bull., vol. 13, p. 77, pl. 56, 1886; The flora of the Amboy clays, p. 91, pl. 43, figs. 1–4; pl. 44, figs. 1–3, 1896.
Berry, New Jersey Geol. Survey Bull. 3, p. 162, pl. 19, fig. 3, 1911.

Newberry's description of this species, published in 1896, is as follows:

> Leaves large, from 10 to 18 centimeters in diameter, general outline circular, deeply two-lobed, sinus reaching below the middle, margin entire, base rounded, lobes oblong or broadly spatulate; nervation strong, radiate or bilateral, midrib slender, from 1 to 4 centimeters in length, running to bottom of medial sinus, there forking equally, each slender branch running parallel with the margin of

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[1] Saporta, G. de, Le monde des plantes avant l'apparition de l'homme, p. 199, fig. 2, 1879.

[2] Velenovsky, Josef, Die Flora der böhmischen Kreideformation, pt. 3, p. 9, pl. 5, fig. 4; pl. 6, figs. 1–4, 1884.

[3] Hollick, Arthur, U. S. Geol. Survey Mon. 50, p. 84, pl. 32, figs. 8, 9, 1907.

[4] Lesquereux, Leo, U. S. Geol. Survey Mon. 17, p. 145, pl. 55, figs. 2, 3; pl. 56, figs. 1, 2; pl. 62, fig. 2, 1892.

[5] Newberry, J. S., U. S. Geol. Survey Mon. 26, p. 90, pl. 41, fig. 14, 1896.

[6] Hollick, Arthur, op. cit., p. 83, pl. 32, figs. 5–7.

[7] Berry, E. W., New Jersey Geol. Survey Ann. Rept. for 1905, p. 138, pl. 22, figs. 1, 2, 1906.

the sinus; lateral nerves strong, usually two, rarely one on each side, springing from a common base, the interior lateral nerve strongest, forking several times and giving off fine branches, which inosculate to form a graceful festoon near the upper margin; the exterior lateral nerves throwing off numerous branches which anastomose in loops near the margin, producing a camptodrome nervation. In those which have but a single lateral nerve the lobes are narrower, and each is covered with the ramification of the branches, which spring chiefly from the outer side of the single main nerve.

The form and nervation of these leaves are so precisely those of some of the Bauhinias of the present flora that there can be no reasonable doubt that we here have the remains of a well-marked species of this genus, which grew near the mouth of the Hudson River in the middle of the Cretaceous age, and was the associate of the magnolias, tulip trees, aralias, etc., which composed the angiosperm forest of eastern North America. In size some of these leaves exceed those of any living bauhinia, and the outline and nervation indicate that the genus was as perfectly defined and highly specialized in the Cretaceous age as now.

The living bauhinias inhabit the tropical and subtropical regions of the Old and New Worlds, India, Mauritius, Surinam, Cuba, Mexico, etc. The genus is closely related to *Cercis*, and most of the species have a similar habit. In a few the leaves are orbicular or slightly emarginate, but they are generally bilobed, the sinus reaching the middle of the leaf, sometimes extending to the base, as is the case with the only species inhabiting the United States, *B. lunaroides* Gray, of Texas and Mexico.

In most of the East India species the nervation is more crowded than in the fossil leaves before us, each nerve having three and sometimes four lateral nerves, the medial nerve, however, being quite the same. In several oriental species, and all those of the New World, the nervation is simpler and especially like that of the fossil.

A fossil species of *Bauhinia* from the Tortonian deposits of Oeningen, Baden, was described by Heer in 1859.[1] Soon afterward Unger described two additional species,[2] both based on pods, from Croatia. Five years later the same author described another species from the Aquitanian of Kumi, Greece.[3] In 1885 Velenovsky described another species from the Cenomanian of Bohemia,[4] without, however, recognizing its true relationship. The next year Newberry described this and another larger species from the middle part of the Raritan formation of New Jersey. In 1908 I described a small but striking new species[5] from the Magothy formation of Maryland and the following new and ornate species from the lower part of the Eutaw formation in Alabama. A late Tertiary species has been described by Cockerell[6] from the Miocene lake deposits at Florissant, Colo.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; Cottondale, Tuscaloosa County, Ala. Eutaw formation (basal part), Havana, Hale County, Ala.

Collections: U. S. National Museum. (The type of this species from New Jersey is in the New York Botanical Garden.)

Bauhinia marylandica Berry.

Bauhinia marylandica Berry, Torreya, vol. 8, p. 218, figs. 1-3, 1908.

Leaves small, about 3 centimeters in greatest length by 2.5 centimeters in greatest breadth, elliptical in general outline, bilobate; the apical sinus narrow and pointed, reaching one-half to two-thirds of the distance to the base; lobes narrow, ascending, somewhat falcate in outline, obtusely pointed; midrib straight, giving off one, two, or three sharply ascending pairs of opposite, camptodrome secondaries, and these give off a series of broadly rounded, inequilateral tertiary arches, which are directly upward and outward; the upper pair of secondaries is the most prominent; from the juncture of the midrib and sinus a pair of much reduced secondaries is given off, and these join the secondary next below in one or two broad arches.

The present species was described in 1908 from the Magothy formation at Grove Point, Md., where it is abundant. It is only sparingly represented in the lower part of the Tuscaloosa formation.

The form and venation of these leaves are exactly like those of several existing forms and are so well marked that there can be no doubt of the existence of a species of *Bauhinia* growing along the middle and south Atlantic coast during the deposition of the Upper Cretaceous, whose descendants along with those of its congeners migrated finally to their present tropical habitat, perhaps gradually with the oscillation of climatic conditions, and perhaps not until the Pleistocene glaciation to the north forced them to make a comparatively sudden retreat southward.

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[1] Heer, Oswald, Flora tertiaria Helvetiae, vol. 3, p. 109, pl. 134, fig. 21, 1859.

[2] Unger, Franz, Sylloge plantarum fossilium, vol. 2, p. 31, pl. 11, figs. 2, 3, 1862.

[3] Unger, Franz, Die fossile Flora von Kumi auf der Insel Euboea, p. 61, pl. 15, fig. 36, 1867.

[4] Velenovsky, Josef, Die Flora der böhmischen Kreideformation, pt. 4, p. 12, pl. 6, fig. 4, 1885.

[5] Berry, E. W., A new Cretaceous *Bauhinia*: Torreya, vol. 8, p. 218, fig. 3, 1908.

[6] Cockerell, T. D. A., Two new fossil plants from Florissant, Colo.: Torreya, vol. 9, p. 184, 1909.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County; Shirleys Mill, Glen Allen, Fayette County, Ala.

Collections: U. S. National Museum.

Bauhinia alabamensis Berry.

Plate XXIII, figure 8.

Bauhinia alabamensis Berry, Am. Jour. Sci., 4th ser., vol. 29, pp. 256-258, text fig. 1, 1910.

Bilobate leaves of medium and large size, 8 to 15 centimeters in greatest length by 11 to 18 centimeters in greatest width. Median sinus rather broad and rounded, reaching two-thirds of the distance toward the base or even more. Lobes somewhat reniform in outline, sublobate, rounded above and with three broadly rounded sublobes on the outer side, the entire margin curving upward and inward from the lower and largest lobe to the truncate or deeply cordate base, which appears to be slightly peltate in some specimens. Midrib comparatively slender, 1.7 to 3 centimeters in length, running to the base of the median sinus and sending off two branches in its upper part, one on each side, which curve upward parallel with the inner margin to join inwardly directed branches from the lateral primaries. Main lateral primaries stout, sending two or three upwardly directed branches inward and three or four longer, less oblique branches outward, the latter forking and forming broad arches in the lateral lobes. One or two additional primaries on each side take their origin from the common point of divergence of the palmate or bilateral system of venation of this species and are confined to the lower lateral lobe on each side along the margin of which their branches arch.

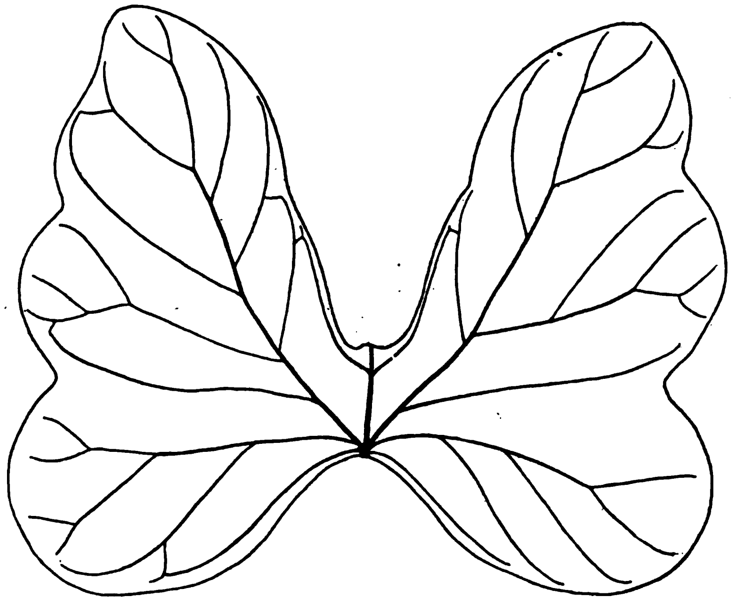

FIGURE 12.—Restoration of *Bauhinia alabamensis*.

This ornate and butterfly-like species of *Bauhinia* is not uncommon in the sandy clays near Havana, in Hale County, Ala., but owing to the unsatisfactory character of the matrix, which is too sandy for good collecting, and also to the fact that the plant remains had evidently been in the water a long time before entombment, only fragmentary specimens were obtained. These represent, however, all parts of the leaf and are complete enough to serve as an entirely accurate basis for the complete leaf shown in the figure 12.

This species is markedly distinct from any of the fossil species hitherto known. In size and general appearance it suggests *Bauhinia cretacea* Newberry, and it may well be a descendant of that species, which, as time passed, widened out and became sublobate. It differs from any existing species known to me in its great width and sublobate character, although several recent smaller-leaved species approach it in the sublobate character, and if representative collections of the foliage of the recent forms showing the limits of specific variation were available for comparison, a tendency would probably be found toward the formation of sublobes. Two recent species were noted as showing this marginal character. These are *Bauhinia hookeri* F. v. Müller of Australia and *Bauhinia tomentosa* Linné of the West Indies.

The display of species of this modern tropical genus in the Upper Cretaceous of the Atlantic Coastal Plain is certainly remarkable, for it embraces very small and very large forms and shows a variety almost as great as that furnished by the existing species.

Occurrence: Eutaw formation (basal beds), 2 miles south of Havana, Hale County, Ala.

Collections: U. S. National Museum.

Bauhinia ripleyensis Berry.

Plate XXIII, figure 7.

Bauhinia ripleyensis Berry, Torrey Bot. Club Bull., vol. 43, p. 294, pl. 16, fig. 1, 1916.

Leaves of medium size, more or less bilobate but much less deeply divided than in the preceding species, obovate in general outline. Length along the midrib, 4.5 centimeters; from apex of lobes to base, 6.7 centimeters. Width across upper part of the leaf, 5.5 centimeters. Apical sinus open, extending about one-fourth of the distance toward the base of the leaf, its margins at the tip of the midrib forming an angle of about 90°, curving slightly upward and then conspicuously outward to the pointed tips of the lobes, which are directed laterally. Outer margins of the leaf full and rounded, becoming straight toward the broadly cuneate base. Midrib of medium size. Lateral primaries branching from the base at angles with the midrib of about 25°, of medium size, curving upward and then outward, and running to the tips of the lobes. They give off four or five camptodrome secondaries on the outside and two or three on the inside. The midrib, in its upper half, also gives off one or two secondaries on each side. Leaf substance somewhat coriaceous.

This species, which is sparingly represented in the argillaceous greensand marls along Cowikee Creek and is associated with shallow water or estuarine mollusks of the Ripley formation, is markedly distinct from any described species of *Bauhinia*. It is much smaller and less deeply divided than *Bauhinia gigantea* Newberry or *Bauhinia alabamensis* Berry and is much less ornate in character. It is, on the other hand, much larger than *Bauhinia marylandica* Berry of the Magothy formation in the Maryland area. It differs from all these American Cretaceous species in its pointed, outwardly directed lobes but is not unlike a number of existing species of this genus.

Occurrence: Ripley formation (Cusseta sand member), right bank of Cowikee Creek, one-eighth of a mile above its mouth, Barbour County, Ala.; (McNairy sand member), 2½ miles southwest of Selmer, McNairy County, Tenn.

Collections: U. S. National Museum.

Genus PALEOCASSIA Ettingshausen.

Paleocassia laurinea Lesquereux.

Plate XXIII, figure 1.

Palaeocassia laurinea Lesquereux, The flora of the Dakota group, p. 147, pl. 64, fig. 12, 1892.

Leaflets ovate-lanceolate in outline, subinequilateral, with a pointed apex and a cuneate base. Length ranging from 3 to 6 centimeters. Maximum width, at or below the middle, about 2 centimeters. Margins entire, somewhat irregular, emarginate halfway up on one side in the figured specimen. Petiolule short, curved, gradually enlarged proximad, about 5 millimeters in length. Midrib of medium size, curved. Secondaries thin, camptodrome.

This species, which was described from the Dakota sandstone of Kansas, is present in the lower part of the Tuscaloosa formation.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

.Collection: U. S. National Museum.

Genus CASSIA Linné.

Cassia vaughani Berry, n. sp.

Plate XXII, figure 8.

Leaflets of relatively large size, elliptical in general outline, with a somewhat extended, obtusely pointed apex, and a broadly rounded base, about 8 centimeters in length by about 4 centimeters in maximum width, which is about midway between the apex and the base. Margins entire, full and rounded. Petiole absent in the material collected. Midrib stout. Secondaries numerous, thin, and more or less obsolete, about ten pairs, camptodrome; they branch from the midrib at angles of 45° or slightly more. Tertiary venation obsolete.

This species, which is named in honor of T. Wayland Vaughan, is clearly new. It resembles the leaves of a number of unrelated tropical genera in the existing flora but stands closest to the genus *Cassia*, greatly resembling a number of existing species and being also identical in its characters with the fossil leaves which European paleobotanists refer to this genus.

The genus *Cassia* in the modern flora has more than 400 species of herbs, shrubs, and trees, which are widely distributed in the warmer parts of both hemispheres, and there is a distinct massing of species in the American tropical and subtropical regions.

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County, Ala.

Collections: U. S. National Museum.

Family PAPILIONACEAE.

Genus PHASEOLITES Unger.

Phaseolites formus Lesquereux.

Plate XXII, figure 7.

Phaseolites formus Lesquereux, The flora of the Dakota group, p. 147, pl. 55, figs. 5, 6. 1892.
(?) Kerner, K.-k. geol. Reichsanstalt Jahrb., Band 45, Heft 1, p. 54, pl. 5, fig. 4, 1895.
Berry, Torrey Bot. Club Bull., vol. 37, p. 198, 1910.

Leaves ovate, inequilateral and somewhat variable in outline, more or less falcate, with an acute apex and base, 5 to 8 centimeters in length by 2.5 to 5 centimeters in maximum width, which is near the middle. Petiole stout, curved, about 1 centimeter in length. Midrib stout below, thin above, curved. Secondaries of medium size, about 8 pairs, branching from the midrib at angles of 45° to 50°, curving upward, camptodrome. Finer venation indistinct. Texture subcoriaceous.

This species was described by Prof. Lesquereux from the Dakota sandstone of Kansas. It was subsequently recorded by von Kerner from the island of Lesina, off the coast of Dalmatia (Cenomanian). The citation is questioned, for the identity of these widely removed occurrences is doubtful, although the actual specimens are very similar in appearance.

I have recorded this species from the lower part of the Black Creek formation in North Carolina, and it is represented by closely allied forms in the northern Atlantic Coastal Plain. In the Alabama area it is known only from the lower part of the Tuscaloosa formation.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Genus COLUTEA Linné.

[Species plantarum, p. 723, 1753.]

Colutea obovata Berry.

Plate XXIII, figure 3.

Colutea obovata Berry, Torrey Bot. Club Bull., vol. 33, p. 175, figs. 5, 6, 1906.

Leaves small, obovate in general outline, inequilateral, with rounded margins and apical auricles separated by a deep and rounded sinus. The Tuscaloosa leaf is somewhat smaller than the type and measures 1.3 centimeters along the midrib, 1.6 centimeters from apices to base, and 1.2 centimeters in greatest width, which is in the distal half of the leaf. Base cuneate. Midrib slightly curved. Secondaries 4 or 5 subopposite pairs which are thin, ascending, and camptodrome. Tertiaries fine, not seen in the material from Alabama.

This small species was described by the writer from material collected in the Magothy formation of Maryland and appears to be entirely distinct from the known Cretaceous species, of which there are several. It resembles more or less some of the leaves which have been identified as *Colutea primordialis* Heer from Greenland, the Atlantic Coastal Plain, and the western interior region.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Genus LIRIODENDROPSIS Newberry.

[U. S. Geol. Survey Mon. 26, p. 82, 1896.]

Liriodendropsis simplex (Newberry) Newberry.

Plate XXII, figure 6.

Liriodendron simplex Newberry, Torrey Bot. Club Bull., vol. 14, p. 6, pl. 62, figs. 2, 3, 1887 (part).
White, Am. Jour. Sci., 3d ser., vol. 39, p. 98, pl. 2, figs. 6, 7, 1890.
Uhler, Maryland Acad. Sci. Trans., vol. 1, p. 207, 189?.
Hollick, New York Acad. Sci. Trans., vol. 11, p. 99, pl. 2, figs. 2, 4, 5, 7, 9, 1892; idem, vol. 12, p. 235, pl. 5, figs. 1, 2, 4, pl. 7, fig. 2, 1893; New York State Mus. Fifty-fifth Ann. Rept., p. 50, 1903.
Pollard, New York Acad. Sci. Trans., vol. 13, p. 180, 1894.
Liriodendropsis simplex (Newberry) Newberry, The flora of the Amboy clays, p. 83, pl. 19, figs. 2, 3; pl. 53, figs. 1-4, 7, 1896.
Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.
Hollick, The Cretaceous flora of southern New York and New England, p. 72, pl. 23, figs. 1-7; pl. 24, figs. 1-9; pl. 25, figs. 1, 4, 5, 7, 10-12; pl. 26, figs. 1b, c, d, 1906.
Berry, New Jersey Geol. Survey Bull. 3, p. 158, pl. 19, fig. 2, 1911.

Leaves or leaflets ovate to ovate-lanceolate in outline, with entire margins, emarginate apex, and cuneate base, ranging from 3 to 10 centimeters in length and from 2.2 to 5 centimeters in width. Midrib stout. Secondaries numerous, camptodrome, their intervals filled by more or less parallel, reticulating, fine tertiaries. The angles of divergence are variable, even in the same leaf, and the peculiarities of preservation obscure the finer venation in some specimens, giving them a strikingly different appearance from others in which the preservation is more complete.

These leaves are exceedingly variable in size and outline. The apex in many specimens is angular at the corners of the leaf blade and at the sinus; in other specimens it is rounded. The sinus may be shallow or moderately deep. The leaflets are much wider than those of *L. angustifolia*, described below, and the width is usually greatest in the upper part, although this feature is far from constant.

This species is very common at a number of localities in the Raritan formation of New Jersey and also on Marthas Vineyard, Long Island, and Staten Island. It is also common in the lower part of the Tuscaloosa formation of western Alabama. None of the American specimens, abundant as they are, show definitely a trifoliate character, but this is indicated by the relative position of the leaflets in some of the specimens figured by Hollick.

These leaves were segregated from *Liriodendron* by Newberry on the basis of their simple nature, emarginate apex, crowded and fine venation, and relatively small size, although their describer says that they are evidently related to *Liriodendron.* Since 1896 much new material has been collected, especially from Long Island. Holm [1] in 1890 suggested that these leaves were not related to *Liriodendron* but were comparable to those of a number of leguminous genera. Somewhat similar leaves were described from Bohemia as *Myrsinophyllum varians* by Velenovsky,[2] and more closely allied forms as *Bignonia pulcherrima* by Bayer,[3] the latter sufficiently well preserved to show their trifoliate nature.

Ward [4] refers a species, described by Saporta as a species of *Chondrophyton* from the Cenomanian of Portugal, to *Liriodendropsis*, to which it is obviously not related, as the writer pointed out some years ago.[5] Recently Hollick [6] has given a résumé of the genus together with descriptions of new species and a large number of illustrations. The probabilities are all in favor of their reference to the Leguminosae, to which family they are referred in the present contribution.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, Fayette County, Ala.

Collections: U. S. National Museum.

Liriodendropsis angustifolia Newberry.

Liriodendropsis angustifolia Newberry, The flora of the Amboy clays, p. 84, pl. 53, fig. 8, 1896.
Smith, On the geology of the coastal plain of Alabama, p. 348, 1894.
Hollick, The Cretaceous flora of southern New York and New England, p. 71, pl. 26, figs. 1a, 2–5, 1906.
Berry, New Jersey Geol. Survey Bull. 3, p. 160, 1911.
Liriodendron simplex Newberry, Torrey Bot. Club Bull., vol. 14, p. 6, pl. 62, fig. 4, 1887 (part).

Leaves or leaflets lanceolate to linear-lanceolate in outline, relatively long and narrow, with an emarginate, generally angular apex and a cuneate base. Size variable, from 6 to 9 centimeters in length by 1.9 to 3 centimeters in greatest breadth, which is never in the upper part of the leaf, the margins as a rule being straight and almost parallel from the angular apical corners, bowing outward slightly in the lower half of the leaf, and curving downward to the rather long petiole. Midrib stout. Secondaries numerous, camptodrome. Tertiaries as in the preceding species.

It may be doubted if this species is anything more than a variant of the preceding species, but as the remains are so abundant it may represent a closely allied, although specifically distinct type. Hollick has described two additional species in the abundant material of this general type contained in the insular Cretaceous flora, namely, *Liriodendropsis constricta* and *L. spectabilis*. He makes *L. spectabilis* one extreme of a series of which *L. angustifolia* Newberry is the other. The relations are obviously as pointed out, but it seems questionable, in view of the individual variation even of these segregates, whether it would not have been better to have considered all these forms as variations of a single species.

The present form is abundant in the middle part of the Raritan formation at Woodbridge, N. J., and also on Marthas Vineyard and at

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[1] Holm, Theodore, U. S. Nat. Mus. Proc., vol. 13, pp. 15–35, 1890; Bot. Gazette, vol. 20, pp. 312–316, 1895.

[2] Velenovsky, Josef, Květena českého cenomanu, p. 25, pl. 4, figs. 8, 9; pl. 5, fig. 12; pl. 6, figs. 10, 11, 1889.

[3] Bayer, Edwin, Studien im Gebiete der böhmischen Kreideformation; Perucer Schichten, p. 156, f. 120a, b, 1901.

[4] Ward, L. F., U. S. Geol. Survey Sixteenth Ann. Rept., pt. 1, p. 540, pl. 107, figs. 6–8, 1896.

[5] Berry, E. W., Torrey Bot. Club Bull., vol. 31, p. 77, 1904.

[6] Hollick, Arthur, The Cretaceous flora of southern New York and New England: U. S. Geol. Survey Mon. 50, pp. 69–73, 1907.

Glen Cove, Long Island. It was recognized by Ward from the Tuscaloosa formation of Alabama and recorded by Smith, as cited in the synonymy, a number of years ago.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, Fayette County, Ala.

Collections: U. S. National Museum.

Liriodendropsis constricta (Ward) Hollick.

Liriodendropsis simplex constricta Ward, U. S. Geol. Survey Sixteenth Ann. Rept., pt. 1, p. 540, pl. 107, fig. 8, 1896.

Liriodendropsis constricta (Ward) Hollick, The Cretaceous flora of southern New York and New England, p. 71, pl. 22, fig. 7; pl. 26, figs. 6–15; pl. 40, fig. 15, 1906.

Liriodendropsis simplex (Newberry) Newberry. Hollick, New York Acad. Sci. Trans., vol. 12, p. 235, pl. 7, fig. 3, 1893.

Leaves ovate in general outline, with a rounded, ultimately cuneate base; constricted abruptly on each side, the apical portion narrowed and straight sided with an emarginate apex. Length ranges from 4 to 9 centimeters. Maximum width, in the basal part, ranges from 2 to 4 centimeters. Secondary and tertiary venation indistinguishable from that of *Liriodendropsis simplex* or *L. angustifolia*, of one or the other of which it is probably a variant and not a distinct species.

Forms which answer to the foregoing diagnosis are recorded from Marthas Vineyard, Mass., and Glen Cove, Long Island, where they are associated with large numbers of leaflets of *Liriodendropsis simplex* and *L. angustifolia.* A single leaflet is likewise associated with these two species in Alabama, which fact lends emphasis to its doubtful specific rank.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

LEGUMINOSAE (position uncertain).

Genus LEGUMINOSITES Bowerbank.

Leguminosites ingaefolia Berry, n. sp.

Plate XXIII, figure 5.

Leaflets of small size, elliptical-lanceolate and slightly inequilateral in general outline, with a rounded apex and base, the apex mucronate and the base correspondingly decurrent. Length about 2.75 centimeters. Maximum width, in the lower half of the leaflet, 6 millimeters to 1.2 centimeters. Margins entire. Texture subcoriaceous. Petiolule stout, curved, about 5 millimeters in length. Midrib stout, flexuous. Secondaries four to six, irregularly spaced, camptodrome pairs, those in the proximal half of the lamina fewer and more ascending than those in the distal half, particularly the lowest secondary. Tertiaries mostly immersed.

This small-leafed species, which is obviously new, is clearly allied to the Leguminosae and is much like some of the Tertiary and existing species of *Inga*, of which a large-leafed species, *Inga cretacea* Lesquereux, occurs in the Tuscaloosa formation, and several species not unlike the present one occur in the Eocene of the Mississippi embayment area.

Occurrence: Tuscaloosa formation, Glen Allen and Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Leguminosites omphalobioides Lesquereux.

Leguminosites omphalobioides Lesquereux, The flora of the Dakota group, pl. 38, fig. 4, 1892.

Newberry, The flora of the Amboy clays, p. 97, pl. 42, fig. 39, 1896.

Berry, Torrey Bot. Club Bull., vol. 37, p. 24, 1910; New Jersey Geol. Survey Bull. 3, p. 155, 1911.

Leaflets elliptical in outline, 3.2 to 4 centimeters in length by 1.5 to 1.7 centimeters in greatest width, which is about halfway between the apex and the base, Texture subcoriaceous. Apex rather broadly rounded. Base slightly narrowed and decurrent to the point of attachment. Lesquereux speaks of a short petiole, but this is lacking in his type figure and in all the specimens examined by the writer. The midrib is not especially wide but is quite prominent. The secondaries are thin and alternate; they number about six pairs and branch from the midrib at angles of 50° or somewhat less, curving upward close to the margins, camptodrome.

This species was described originally from the Dakota sandstone of Kansas. The Tuscaloosa leaf is very close to the type, differing merely in that the outline is more nearly elliptical than it is in the western form.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Leguminosites shirleyensis Berry, n. sp.

Plate XXIII, figure 4.

Diospyros rotundifolia Lesquereux, The flora of the Dakota group, pl. 17, fig. 11 (not figs. 8–10), 1892.

Leaflets of small size, orbicular or elliptical in general outline, with a rounded or slightly retuse apex. Base rounded, slightly inequilateral, abruptly decurrent to form linear wings along the lateral margins of the petiolule. Length about 1.75 centimeters. Maximum width, in the middle part of the leaflet, about 1.1 centimeters. Margins entire, slightly irregular. Petiolule stout, alate, about 3 millimeters long. Midrib stout proximad, becoming attenuated in a short distance distad. Secondaries thin, irregularly spaced, about six camptodrome pairs.

This small leaflet appears to be related to the Leguminosae, although it is similar to the leaves of a number of unrelated genera, as for example, *Celastrophyllum*, *Bumelia*, *Vaccinium*, and various Rhamnaceae. It is believed to represent an Upper Cretaceous species of the Leguminosae or possibly of the Rhamnaceae. The small leaf from the Dakota sandstone which Lesquereux referred to *Diospyros rotundifolia* is obviously identical with this species from Alabama and is quite unlike the usual forms of *Diospyros rotundifolia*.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Leguminosites tuscaloosensis Berry, n. sp.

Plate XXIII, figure 6.

Leaflets of medium size, sessile, ovate-lanceolate and markedly inequilateral in general outline, with a cuneately pointed apex and a decurrent base. Length about 3 to 5 centimeters. Maximum width, about midway between the apex and the base, 1.5 to 2.5 centimeters, one side commonly about twice the width of the other. Petiolule wanting. Midrib thin and curved, stout at base. Secondaries thin, numerous, subparallel, diverging from the midrib at acute angles and camptodrome, more or less immersed in the leaf substance. Tertiaries obsolete. Margins entire. Texture subcoriaceous.

These more or less falcate leaflets are unlike previously described forms and appear to be referable to the Leguminosae, resembling a variety of recent forms in each of the families into which the old family has been segregated in recent years.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Order GERANIALES.

Family RUTACEAE.

Genus CITROPHYLLUM Berry.

Citrophyllum aligerum (Lesquereux) Berry.

Ficus aligera Lesquereux, The flora of the Dakota group, p. 84, pl. 10, figs. 3–6, 1892.

Berry, Torrey Bot. Club Bull., vol. 33, p. 172, 1906; New Jersey Geol. Survey Ann. Rept. for 1905, p. 139, 1906.

Citrophyllum aligerum (Lesquereux) Berry, Torrey Bot. Club Bull., vol. 36, p. 258, pl. 18a, figs. 1–8, 1909; New Jersey Geol. Survey Bull. 3, p. 169, pl. 21, figs. 1–8, 1911.

Leaves small, elliptical to ovate or ovate-lanceolate in outline, coriaceous, ranging from 2.5 to 6 centimeters in length by 1.8 to 3.2 centimeters in width. Margins entire, in some specimens slightly undulate. Apex rounded or obtusely acuminate. Base rounded, subtruncate or cuneate. Petiole stout, 0.7 centimeter to 2 centimeters in length, conspicuously alate. The petiolar wings may be oblong-lanceolate or obovate; together they are from 2.5 to 5 millimeters in width, averaging about 3.5 millimeters. Midrib stout. Secondaries fine, more or less obscured by the coriaceous leaf-substance, about 9 alternate pairs, branching from the midrib at angles of 45° to 50°, parallel, camptodrome.

These curious leaves were described by Lesquereux from the Dakota sandstone as a species of *Ficus* and compared with *Ficus bumelioides* Ettingshausen and *Ficus mudgei* Lesquereux, neither of which has alate petioles, and the first has an emarginate apex. Subsequently the same leaves were found in the Magothy formation of New Jersey and only recently a single small leaf was found in the upper beds of the Raritan formation of South Amboy, N. J. They have also been recognized in the Black Creek formation of North Carolina and in the Middendorf arkose member of the Black Creek formation of South Carolina. They exhibit considerable variability in outline, but all have exactly the same aspect and conspicuous alate petioles.

They appear to be related to the leaves of the modern genus *Citrus*, which have exactly the same texture and venation, the same variability in outline and marginal undulations, the same stout midrib and conspicuously alate petioles. In examining a suite of specimens of leaves of *Citrus* and comparing them with the fossils, the conclusion seems irresistible that they are related, and the writer has consequently referred the fossils to a new genus with a name that emphasizes this relationship to the modern genus

Possible arguments against the present view may be based on the theory that the modern alate petioles are derived from ancestors with compound leaves; in fact, some modern species still have trifoliate leaves, and if this were true of the fossils as well it would require considerable rapidity of evolution in this genus previous to the middle Cretaceous. The modern leaves absciss from the top of the petiole and would be unlikely to occur as fossils with the petiole attached, neither can any indication of such an abscission line be made out in the fossils. This argument is difficult to combat. However, modern leaves are sometimes shed in their entirety, and we are justified in predicating the occasional fall of leaves before maturity, when the abscission layer of cells has not yet become weakened. The agency might be violent winds, the passage of large animals like some of the Cretaceous dinosaurs, or weakened conditions due to insect or fungous diseases.

The Tuscaloosa forms are of the elliptical type occurring in the Raritan formation of New Jersey and in the Dakota sandstone of the West. Some of the western leaves are more elongated, as are those collected from the Magothy and Black Creek formations and the Middendorf member. It is possible that two species are represented, but if so, differential specific characters are not obvious. The genus is represented by well-marked species in the undescribed collections from the lower Eocene (Wilcox group) and middle Eocene (Claiborne group) of the Mississippi embayment area.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County; Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Family EUPHORBIACEAE.

Genus CROTONOPHYLLUM Velenovsky.

Crotonophyllum panduraeformis Berry.

Crotonophyllum panduraeformis Berry, U. S. Geol. Survey Prof. Paper 84, p. 48, pl. 7, figs. 5-10, 1914.

Leaves of variable size and irregular panduriform outline, about 8 to 10 centimeters in length by 3 to 4 centimeters in greatest width, which is in the basal half of the leaf. General outline ovate, separated by a sharp lateral sinus on each side into a broad basal portion with full rounded margins, and an upper narrower portion which is more or less rounded or elongated. In some specimens the sinus is wanting on one side, and it may be wanting on both sides and the leaf be ovate-lanceolate in outline if the habit of the Bohemian species is any criterion. Tip bluntly pointed, dependent on the width of the apical segment. Base slightly decurrent to the stout petiole, which is of considerable length. Texture coriaceous. Midrib stout. Secondaries numerous, rather stout, branching from the midrib at angles of about 45°, parallel, camptodrome below and in some specimens also in the apical portion of the leaf; in these specimens they pursue an upwardly curved course. In other specimens they are straight in the apical half of the leaf, and their ends are connected by a nearly straight marginal vein, which is the continuation of some lower secondary; in fact the regularly camptodrome lower secondaries are parallel with the margin before they finally inosculate.

These curious leaves are not uncommon in the Middendorf arkose member of the Black Creek formation of the South Carolina Cretaceous, although they are generally incomplete. They are wholly unlike any American Cretaceous leaves, although they suggest the leaf described from the Upper Cretaceous of Vancouver Island by Dawson as *Liriodendron succedens*.[1] That leaf is hardly a Liriodendron, but Dawson's figures are all inaccurate, and as the writer has not seen the original material, no conclusion on this point is legitimate. The genus *Crotonophyllum* was proposed by Velenovsky for leaves from the Cenomanian of

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[1] Dawson, J. W., Roy. Soc. Canada Trans., vol. 11, sec. 4, p. 62, pl. 8, fig. 6, 1893.

Vyserovic, Bohemia, which are very similar to the present species. A single species, *Crotonophyllum cretaceum*,[1] was described and compared with the existing species of Croton, but as the discussion is in Bohemian it can not be followed without a translation. The illustrations are, however, ample and depict a leaf which is surely congeneric with the American species. The genus is also represented by undescribed forms from the lower Eocene (Wilcox group) of the Mississippi embayment area.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Genus MANIHOTITES Berry.

Manihotites georgiana Berry.

Manihotites georgiana Berry, Torrey Bot. Club Bull., vol. 37, p. 507, figs. 1, 2, 1910; U. S. Geol. Survey Prof. Paper 84, p. 114, pls. 22, 23, 24, figs. 4, 5; text figs. 2, 3, 1914; Torrey Bot. Club Bull., vol. 43, p. 295, 1916.

This remarkable form was recently described by me in the papers cited above, and the discussion need not be repeated here.

Occurrence: Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga.; (Coffee sand member), Coffee Bluff, Hardin County, Tenn. Ripley formation (Cusseta sand member), near Buena Vista, Marion County, Ga.; (McNairy sand member), 2½ miles southwest of Selmer, McNairy County, Tenn.

Collections: U. S. National Museum.

Order SAPINDALES.

Family ILICACEAE.

Genus ILEX Linné.

Ilex masoni Lesquereux.

Ilex masoni Lesquereux, The flora of the Dakota group, p. 179, pl. 7, fig. 6; pl. 63, fig. 6, 1892.

The original description of this species by Lesquereux, which was published in 1892, is as follows:

> Leaf subcoriaceous, linear-oblong, slightly enlarged in the lower part, cuneiform to the base, apparently obtuse (point broken) repand-dentate on the borders; primary nerve comparatively thick; secondaries open, arched in passing toward the borders, camptodrome, anastomosing in broad, angular curves at a distance from the borders to which they are joined by branches at right angles to the curves.
>
> The first leaf is about 12 centimeters long, 4.5 centimeters broad below the middle, where it is slightly enlarged, is marked by a few obtuse teeth, the upper part being entire or slightly undulate. The lower pair of secondaries are thin, at a more acute angle of divergence, 50°, inequidistant, parallel, somewhat strong, distinctly camptodrome, the upper pair appearing more curved in ascending toward the apex. The bows formed by angular anastomosis of the secondaries at a short distance from the borders are linked to them by short nervilles at right angles. The surface is smooth, nearly polished, indistinctly marked by transverse nervilles. The other fragment indicates a leaf scarcely broader but much longer, broken at both ends, and cut in deeper, large teeth.
>
> These leaves resemble those of *Ilex borealis* Heer[2] but are larger, also *Ilex longifolia* Heer,[3] the borders of which are also minutely dentate, etc.

Whatever may be thought of the botanic affinity of this relatively large-leafed species as determined by Lesquereux, it is certainly not uncommon in the lower part of the Tuscaloosa formation, although the material is for the most part rather fragmentary.

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County; Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Family CELASTRACEAE.

Genus CELASTROPHYLLUM Goeppert.

Celastrophyllum decurrens Lesquereux.

Celastrophyllum decurrens Lesquereux, The flora of the Dakota group, p. 172, pl. 36, fig. 1, 1892.
Berry, New Jersey Geol. Survey Bull. 3, p. 176, pl. 22, fig. 8, 1911.
Celastrophyllum angustifolium Newberry, The flora of the Amboy clays, p. 100, pl. 14, figs. 8–17, 1896.

Leaves of variable size, lanceolate in general outline. Length ranging from 5 to 15 centimeters. Maximum width, in the middle part of the leaf, ranging from 1.5 to 4 centimeters. Apex usually acuminate, rarely subacute. Base narrowed and decurrent. Margins entire near the base, above this they are serrulate or finely crenate-dentate. Petiole stout, curved. Midrib stout, usually curved or flexuous. Secondaries thin, numerous, usually about 2 millimeters apart, subparallel, diverging from the midrib at angles of 40° to 45°, finally branching and forming an intricate network along the margin, the ultimate branches running directly to the margin. Texture subcoriaceous.

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[1] Velenovsky, Josef, Květena českého cenomanu, p. 20, pl. 5, figs. 4–11, 1889.

[2] Heer, Oswald, Flora fossilis arctica, vol. 7, p. 39, pl. 64, figs. 3, 4, 1883.

[3] Idem, vol. 1, p. 124, pl. 48, figs. 3, 4, 1868.

This species was based on a single specimen from the Dakota sandstone of Kansas. It is common from the base to the top of the Raritan formation in New Jersey. Only one specimen has been found in the Tuscaloosa formation. It is very similar to *Myrica fragiliformis* (Zenker) Engelhardt,[1] a species described from the Cenomanian of Saxony[2] and recorded under the name *Myrica zenkeri* Heer from the Atane beds of Greenland[3] and the Magothy formation at Glen Cove, Long Island.[4] The form from Long Island is an extremely questionable identification.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Celastrophyllum shirleyensis Berry, n. sp.

Plate XXIV, figures 3, 8.

Leaves of medium to small size, elongate-elliptical in general outline, with a somewhat narrowed, rounded tip, and a broadly rounded base. Length about 5.25 centimeters. Maximum width, in the lower part of the leaf, about 1.7 centimeters. Margins irregularly dentate, the teeth directed laterally. Texture subcoriaceous. Petiole not preserved, evidently stout. Midrib stout, curved, prominent. Secondaries stout, about 11 opposite to alternate pairs, variably spaced, diverging from the midrib at wide angles of 55° to 70°; the basal pairs craspedodrome; the distal pairs regularly camptodrome; the median pairs forking and anastomosing and sending branches to the margins.

The present species is similar to *Celastrophyllum brittonianum* Hollick but differs in being widest below instead of above the middle, in having the marginal teeth larger and crenate instead of denticulate, and in the less numerous and earlier forked secondaries. It also resembles somewhat the Patapsco species *Celastrophyllum acutidens* Fontaine, which is, however, a coarser leaf with very large irregular teeth and more ovate form. It is also much like *Celastrophyllum albaedomus* Ward,[5] a Patapsco species with which I at one time confused it.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Celastrophyllum undulatum Newberry.

Celastrophyllum undulatum Newberry, The flora of the Amboy clays, p. 102, pl. 38, figs. 1-3, 1896.

Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894 (nomen nudum).

Berry, New Jersey Geol. Survey Bull. 3, p. 175, 1911.

Leaves of large size, 10 to 15 centimeters in length by 4 to 8 centimeters in breadth, ovate-oblong or ovate in outline, with an obtuse or bluntly pointed apex and somewhat narrowed base. Margin strongly undulate or broadly and coarsely crenate, somewhat variable in the character of its teeth. Midrib stout. Secondaries numerous, a dozen or more subopposite pairs, which branch from the midrib at a wide angle and fork near the margins to form festoons, which coincide approximately with the marginal teeth.

This very large species resembles the larger leaves that are referred to *Celastrophyllum crenatum* Heer but is much larger and more elongate in outline. Its size has apparently rendered perfect specimens rare, and as a rule the remains that are obtained are fragmentary. Velenovsky hints at its identity with the leaves named by him *Myrica zenkeri* from the Bohemian Cretaceous, although this resemblance is obviously slight, the present species more nearly resembling the Bohemian leaves which this author identifies as a species of *Ternstroemia,* as well as various lower Eocene species of *Ternstroemites* of the Mississippi embayment area.

It was described originally from the Raritan formation of New Jersey and is represented by considerable fragmentary material in the lower beds of the Tuscaloosa formation. Large leaves of this species occur in the Black Creek formation of North Carolina.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

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[1] Engelhardt, Hermann, Naturwiss. Gesell. Isis in Dresden Abh. 7, Jahrg. 1891, p. 93, 1892.

[2] Ettingshausen, C. von, Die Kreideflora von Niederschoena in Sachsen, p. 23, pl. 3, figs. 1, 3, 10, 11, 1867.

[3] Heer, Oswald, Flora fossilis arctica, vol. 3, Abt. 2, p. 108, pl. 31, fig. 2, 1874.

[4] Hollick, Arthur, U. S. Geol. Survey Mon. 50, p. 54, pl. 7, fig. 23, 1907.

[5] Ward, L. F., Status of the Mesozoic flora of the United States: U. S. Geol. Survey Mon. 48, p. 489 (footnote), pl. 108, fig. 3, 1906.

Celastrophyllum newberryanum Hollick.

Celastrophyllum newberryanum Hollick, in Newberry. The flora of the Amboy clays, p. 101, pl. 49, figs. 1-27, 1896; New York Acad. Sci. Trans., vol. 16, p. 133, pl. 14, fig. 1, 1897.

Knowlton, in White and Schuchert, Geol. Soc. America Bull., vol. 9, p. 353, 1898.

Berry, New York Bot. Garden Bull., vol. 3. p. 86, 1903; Torrey Bot. Club Bull., vol. 31, p. 78, 1904; New Jersey Geol. Survey Bull. 3, p. 174, pl. 22, figs. 5-7, 1911.

Leaves of medium size, 2.5 to 6 centimeters in length by 1 to 2.5 centimeters in maximum width, ranging in outline from narrowly to broadly ovate or obovate. Apex somewhat rounded, although it may be acute or apiculate in the narrower form. Base somewhat cuneate and slightly decurrent. Margins entire in the basal third of the leaf, in some specimens so throughout, elsewhere with mostly small, closely set, appressed denticles. Midrib rather stout. Secondaries five or six pairs, branching from the midrib at angles of about 45°, curved, camptodrome.

In size, outline, and venation this species, which is exceedingly abundant, is very close to modern members of the family Celastraceae and may be compared with our existing *Celastrus scandens* Linné, which it closely resembles.

It is probably present in the Atane beds of Greenland in some of the leaves which Heer includes under his *Celastrophyllum crenatum*, and it has been reported by Hollick from the Magothy formation at Cliffwood Bluff, N. J., where it is apparently rare. It would seem as if such an abundant element in the late Raritan, which reappears in the Tuscaloosa formation of Alabama, would be present in allied floras at intermediate points, but as yet its presence has not been detected.

Forms from the Bohemian Cretaceous that are practically identical with the smaller and more pointed leaves of this species are referred by Velenovsky to the genus *Phillyrea* of the Oleaceae, and compared with the living *Phillyrea latifolia* Linné of southern Europe.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Celastrophyllum grandifolium Newberry.

Plate XXIV, figure 5.

Celastrophyllum grandifolium Newberry, The flora of the Amboy clays, p. 104, pl. 19, fig. 8; pl. 21, figs. 1-4, 1896.

Hollick, The Cretaceous flora of southern New York and New England, p. 88, pl. 33, fig. 8, 1906.

Berry, New Jersey Geol. Survey Bull. 3, p. 179, pl. 23, fig. 1, 1911.

Leaves large, 10 to 25 centimeters in length by 3.5 to 7 centimeters in maximum width, ovate-lanceolate in outline. Apex rounded or subacute. Base varying from rounded to cuneate. Margins entire below, above somewhat irregularly undulate or closely serrate, or with coarse rounded teeth. Petiole long (maximum length 4.5 centimeters), very stout. Midrib stout. Secondaries numerous and slender for such large leaves, 12 to 15 pairs, branching from the midrib at angles of 45° or slightly more, somewhat flexuous and irregular in their course, camptodrome. Tertiaries generally transverse, forming a coarsely quadrangular areolation.

This species is quite variable not only in size but especially in marginal characters, which show every gradation from nearly entire forms to closely serrate forms. This variation is more or less characteristic of all the species of this genus. This species, however, is very distinct, its nearest ally apparently being *Celastrophyllum lanceolatum*, which is described by Ettingshausen from the Cretaceous of Saxony,[2] and which Heer apparently recognized in his material from Greenland.[3]

This species is very common in the Raritan formation of New Jersey but is sparingly represented in the Tuscaloosa collections. None of the very large forms have been discovered at Shirleys Mill, and at first sight the two appear to be entirely distinct. However, the Raritan form shows a series of gradations, and the smaller leaves are identical with the figured specimen from the Tuscaloosa. Fragments of large leaves of this species are found at the Cottondale locality.

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[1] Velenovsky, Josef, Die Flora der böhmischen Kreideformation, pt. 1, p. 7, pl. 4, figs. 2-5, 1885.

[2] Ettingshausen, C. von, Die Kreideflora von Niederschoena in Sachsen, p. 260, pl. 3, fig. 9, 1867.

[3] Heer, Oswald, Flora fossilis arctica, vol. 7, p. 40, pl. 54, fig. 9a; pl. 55, figs. 7, 8, 1883.

This and other Cretaceous species commonly referred to *Celastrophyllum* greatly resemble the leaves of various modern tropical species of the family Ternstroemiaceae (Theaceae) and it is quite possible that they may represent ancestral types of this family. This relationship is further indicated by the presence of types belonging to this family in the Wilcox and Claiborne groups of the Eocene of the embayment area, which I have described as species of *Ternstroemites*.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Celastrophyllum carolinensis Berry.

Plate XXIV, figures 6, 7.

Celastrophyllum carolinensis Berry, U. S. Geol. Survey Prof. Paper 84, p. 51, pl. 13, figs. 1-5, 1914.

Leaves lanceolate in outline, with a pointed apex and a cuneate base, maximum dimensions about 14 centimeters in length by 2.9 centimeters in width, which is about midway between the apex and the base, tapering equally in both directions. Midrib stout, rather flexuous. Secondaries numerous, thin, branching from the midrib at acute angles of 45° or less, curving upward, usually camptodrome, some of them craspedodrome in the upper part of the leaf; sending tertiary branches into the marginal teeth. Margins entire for a short distance at the base, above which they are crenate or biconvex, the teeth large, interspersed with smaller subordinate teeth of the same character. Leaf substance thin.

This striking form is rather common at a single locality in the Middendorf arkose member of the Black Creek formation of South Carolina, but the leaves are always much broken, although fragments of all parts of the leaf are present. The Alabama material is also badly macerated.

This species has been compared with a very large amount of material of existing species in the National Herbarium and in that of the New York Botanical Garden. It shows analogies with a variety of existing genera, as, for example, *Cunonia*, *Clerodendron*, *Symplocos*, *Ternstromia*, and *Panax*, but is believed to find its nearest relatives among the Celastraceae, although the possibility of this species as well as *Celastrophyllum grandifolium* Newberry being referable to the family Ternstroemiaceae should not be overlooked. It is not close to any described fossil species, although there is a general resemblance to a number of the American Cretaceous species of *Celastrophyllum*. There is also a general resemblance to *Grevilleophyllum constans*[1] and *Aralia coriacea*,[2] both Cenomanian species described by Velenovsky from Bohemia. Leaves of this sort have also been referred to *Dryandroides* (cf. *D. quercinea* Velenovsky), *Myrica* (cf. *M. serrata* Velenovsky), *Quercus*, and *Fraxinus*.

Occurrence: Tuscaloosa formation, upper ravine and big gully on the Snow place, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Celastrophyllum crenatum Heer.

Celastrophyllum crenatum Heer, Flora fossilis arctica, vol. 7, p. 41, pl. 62, fig. 2, 1885.
Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.
Newberry, The flora of the Amboy clays, p. 99, pl. 68, figs. 1-19, 1896.
Berry, Torrey Bot. Club Bull., vol. 34, p. 197, pl. 13, fig. 5, 1907; New Jersey Geol. Survey Bull. 3, p. 178, pl. 22, fig. 9; pl. 23, fig. 2, 1911.

Leaves very variable in size, 2 to 8 centimeters in length by 1 to 5 centimeters in width, ovate or elliptical in outline, broadly rounded above, narrowed and generally inequilateral below. Margins entire below, coarsely toothed above, with somewhat variable, rounded, crenate, or crenate-dentate teeth. A few specimens are entire throughout and some have a markedly inequilateral base. Midrib rather stout. Secondaries numerous, nine or ten pairs, subopposite, branching from the midrib at angles somewhat in excess of 45°, slightly curved upward and parallel, branching near the margin to form festoons from which branches enter the marginal teeth.

This species was described originally by Heer from the Patoot beds of Greenland, but unfortunately only a single small leaf was figured. The Raritan leaves that have been identified as *Celastrophyllum crenatum* are abundant and grade into much larger forms, which are also present in the Black Creek formation of North Carolina and the Tuscaloosa formation of Alabama.

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[1] Velenovsky, Josef, Die Flora der böhmischen Kreideformation, pt. 2, p. 3, pl. 1, figs. 6-10, 1883.

[2] Idem, pt. 3, p. 11, pl. 1, figs. 1-9; pl. 2, fig. 2, 1884.

The species is rare in South Carolina, fragmentary specimens being sparsely represented in the Middendorf arkose member of the Black Creek formation. The genus is characteristic of the late Lower and the Upper Cretaceous of eastern North America.

Occurrence: Tuscaloosa formation, Cottondale and big gully on the Snow place, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Celastrophyllum crenatum ellipticum Berry, n. var.

Plate XXIV, figures 1, 2.

Leaves of small to medium size, elliptical to orbicular in outline, ranging from 2.2 to 5 centimeters in length by 1.5 to 4.5 centimeters in maximum width, which is midway between the apex and the base. Apex broadly and evenly rounded. Base equally rounded, narrowly and inconspicuously decurrent. Margins entire for a short distance at the base, passing gradually into large crenate and biconvex teeth which are typically those of *Celastrophyllum crenatum* Heer. Petiole stout, curved, 1 to 1.5 centimeters in length. Midrib of medium size. Secondaries thin, few in number, about five pairs, branching from the midrib at angles of 45° or more, camptodrome.

The present well-marked variety differs from the type in its orbicular or elliptical instead of obovate outline, in its fewer secondaries, longer petiole, and in the nearer approach to the base of the marginal teeth. The younger leaves are elliptical, but the older ones, which are slightly smaller than the average for the type, are nearly orbicular.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Celastrophyllum alabamensis Berry, n. sp.

Plate XXIV, figures 10–12.

Leaves of small to medium size, elliptical in general outline, showing a tendency in the larger specimens toward a somewhat trilobate form. Length ranges from 1.75 to 10 centimeters. Maximum width, which is in the basal half of the leaf, ranges from 1 to 9 centimeters. Margin somewhat irregularly crenate, with large and small teeth, some of which are dentate, though the larger ones are broad scallops, exactly similar to the marginal characters so well shown in *Celastrophyllum crenatum* Heer. Petiole of medium length, 4 millimeters in the smallest specimen figured, 2 centimeters in larger specimens, rather stout and curved. Midrib relatively stout. Secondaries stout, about six pairs, branching from the midrib at angles of about 45°, craspedodrome, sending off curved craspedodrome tertiaries to the subordinate teeth, especially laterally from the lowest pair.

This species is exceedingly variable in size and appearance, ranging from small elliptical leaves similar to those of *Celastrophyllum crenatum ellipticum* Berry to large forms, somewhat triangular in outline, almost trilobate, with toothed lobules at the apex of each secondary, suggestive of *Betula nigra* Linné or *Crataegus coccinea* Linné. It is, as a whole, entirely distinct from the rather numerous forms of *Celastrophyllum* that are present in the Tuscaloosa formation of Alabama or in homotaxial deposits in the Upper Cretaceous of the Atlantic Coastal Plain, where this genus is so well represented.

This species is only known from the single locality cited, where it is exceedingly abundant in all sizes and is the only recognizable form in the collection.

Occurrence: Tuscaloosa formation, 4 miles east of Centerville on Centerville-Randolph road, Bibb County, Ala.

Collections: U. S. National Museum.

Celastrophyllum brittonianum Hollick.

Plate XXIV, figure 4.

Celastrophyllum brittonianum Hollick, in Newberry, The flora of the Amboy clays, p. 105, pl. 42, figs. 37, 38, 46, 47, 1896.

Ward, U. S. Geol. Survey Fifteenth Ann. Rept., pp. 349, 358, 377, 378, 379, 1895; Status of the Mesozoic floras of the United States, p. 492, pl. 107, fig. 7, 1905.

Berry, New Jersey Geol. Survey Bull. 3, p. 180, 1911; Maryland Geol. Survey, Lower Cretaceous, p. 479, pl. 90, fig. 3, 1911.

Leaves small, 4 to 5 centimeters in length by 1.2 to 2.1 centimeters in maximum width, ovate-lanceolate or in some specimens somewhat spatulate in outline. Apex subacute. Base somewhat decurrent and straight sided (cuneate). Margins entire below, denticulate above. Midrib rather stout. Secondaries numerous, somewhat irregular, branching from the midrib at angles of about 45°, of fine caliber but prominent, camptodrome.

This species, which was described originally from the Raritan formation of New Jersey, is clearly distinct from *Celastrophyllum spatulatum* Newberry, although it stands nearer to that form than to any other that is known. It seems to be a somewhat older type, for it has been recognized in the considerably older deposits of the Patapsco formation (Albian) in Virginia. It would be interesting to know from what horizon or horizons in the Raritan formation it had been collected, but Newberry failed to indicate the locality in connection with any of his several specimens, and it has not been collected in that region since his day.

Though not common in the Tuscaloosa formation of western Alabama unquestionable remains of this species occur in the lower beds, and it is one of the very few species which survived from the Lower Cretaceous. It resembles somewhat *Celastrophyllum albaedomus* Ward, which is associated with it, but differs in the more spatulate outline, the finer denticulate teeth, and the more numerous, less ascending, and less branched secondaries.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Celastrophyllum gymindaefolium Berry, n. sp.

Plate XXIV, figure 9.

Leaves more or less inequilateral, obovate in outline, with a broadly rounded, in some specimens slightly retuse, apex, and a narrowed decurrent base. Length 3 to 3.5 centimeters, maximum width, at or above the middle, 2 centimeters, or slightly more. Petiole short and stout, curved, 3 to 4 millimeters in length. Midrib stout below, becoming thin distad. Secondaries very thin, diverging at an acute angle, forking and arching to form oblanceolate meshes, the points of the meshes directed inward from the margin. Margins entire. Texture coriaceous.

This handsome species is clearly distinct from previously described species of *Celastrophyllum*, and it is as clearly related to the modern *Gyminda grisebachii* Sargent, which is a small tree that ranges from the Florida Keys through the West Indies to Trinidad and is found also in southern Mexico and Central America. This resemblance is most marked; the leaves of the modern species in their short petiole, more or less inequilateral blade, decurrent base, and broadly rounded apex, as well as in their texture and venation, are identical with their Upper Cretaceous ancestor.

In accordance with custom the fossil form is referred to *Celastrophyllum*, a form genus for leaves of this family, and the specific name chosen denotes the remarkable resemblance to its existing representative, the genus *Gyminda*.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala. (Collected by E. W. Berry.)

Collection: U. S. National Museum.

Celastrophyllum praecrassipes Berry, n. sp.

Plate XXIV, figure 13.

Leaves of small size, orbicular in general outline, with an equally rounded apex and base. Diameter about 1.5 centimeters. Margins entire. Texture subcoriaceous. Petiole missing, presumably short and stout. Midrib stout below, slender distad, flexuous. Secondaries thin, three or four, irregularly spaced, camptodrome pairs.

The present species is named from its resemblance to the smaller leaves of the Dakota sandstone species, *Celastrophyllum crassipes* Lesquereux,[1] and is clearly referable to the Celastraceae or Rhamnaceae. It is not unlike *Celastrophyllum latifolium* Fontaine[2] of the Patapsco formation and is also similar to the more nearly contemporaneous *Celastrophyllum minus* Hollick[3] of the Raritan formation.

Occurrence: Tuscaloosa formation. Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Family SAPINDACEAE.

Genus SAPINDUS Linné.

Sapindus variabilis Berry, n. sp.

Plate XXVII, figures 1-3.

Leaflets differing greatly in size and outline, ranging from small lanceolate forms like the smallest specimen figured, which is 5 centimeters in length by 1.2 centimeters in maximum width, to forms like the largest specimen figured, which is oblong-elliptical in outline and 10 centimeters in length by 3 centimeters in maximum width. All are inequilateral, the majority markedly so, and many are falcate. The apex varies from an acute point but slightly elongated to forms in which the lamina is abruptly contracted to a long, slender acumen. The base is conspicuously decurrent and inequilateral. Margins entire. Texture coriaceous. Petiolule broad and flat, reaching a maximum length of 1.3 centimeters. Midrib stout below, becoming thin distad, more or less curved. Secondaries numerous, thin, subparallel, diverging from the midrib at angles of about 45°, rather straight, ultimately camptodrome, largely immersed in the leaf substance. Tertiaries obsolete.

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[1] Lesquereux, Leo, The flora of the Dakota group, p. 174, pl. 57, figs. 6, 7, 1892.

[2] See Berry, E. W., Maryland Geol. Survey, Lower Cretaceous, p. 477, pl. 90, figs. 6-9, 1911.

[3] Hollick, Arthur, in Newberry, J. S., The flora of the Amboy clays: U. S. Geol. Survey Mon. 26, p. 105, pl. 42, figs. 51, 52, 1895.

This characteristic species is abundantly represented in the collections from Shirleys Mill, occurring rather sparingly at Glen Allen. Its range of size and variation are well shown in the accompanying illustrations. It resembles more or less several previously described fossil species, as, for example, *Sapindus diversifolius* Lesquereux[1] of the Dakota sandstone, which has a more prominent venation and which is represented in the Magothy formation of New Jersey and Long Island by the specimens erroneously identified by Hollick[2] as *Sapindus apiculatus* Velenovsky,[3] a species which comes from the European Cenomanian and which is also much like the present species. Both the species mentioned are most like the smaller leaflets of *Sapindus variabilis*. A form that resembles the larger leaflets is *Sapindus caudatus* Lesquereux,[4] which occurs in the basal Eocene of Colorado. Among recent species there are several tropical American forms that have leaflets very close to this fossil form.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, Fayette County, Ala.

Collection: U. S. National Museum.

Sapindus morrisoni Heer (Lesquereux MS.).

Sapindus morrisoni Heer, Flora fossilis arctica, vol. 6, pt. 2, p. 96, pl. 40, fig. 1; pl. 41, fig. 3; pl. 43, figs. 1a, b; pl. 44, figs. 7, 8, 1882; idem, vol. 7, p. 39, pl. 65, fig. 5, 1883.

Lesquereux, The Cretaceous and Tertiary floras, p. 83, pl. 16, figs. 1, 2, 1883; The flora of the Dakota group, p. 158, pl. 35, figs. 1, 2, 1892.

Hollick, New York Acad. Sci. Ann., vol. 11, p. 422, pl. 36, fig. 4, 1898; The Cretaceous flora of southern New York and New England, p. 90, pl. 33, figs. 16-20, 1906.

Knowlton, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 317, 1901.

Berry, N. Y. Bot. Garden Bull., vol. 3, p. 83, pl. 47, figs. 2, 3, 1903; Torrey Bot. Club Bull., vol. 31, p. 78, 1904; New Jersey Geol. Survey Ann. Rept. for 1905, pp. 138, 139, 1906.

Leaflets of variable, generally large size, lanceolate and more or less inequilateral in outline, with a broadly cuneate or rounded base and a pointed tip. Petiolulate. Texture subcoriaceous. Margins entire. Midrib stout, curved. Secondaries numerous, camptodrome.

The present species was described originally by Heer from West Greenland, to whom it must be credited, although it was based on Lesquereux's manuscript which appeared in print the following year. It is common in the Dakota sandstone of the West and in the Magothy formation of the northern Atlantic Coastal Plain and occurs in the Woodbine sand of the western Gulf area (Texas).

Occurrence: Tuscaloosa formation, roadside southwest of Northport, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Order RHAMNALES.

Family RHAMNACEAE.

Genus ZIZYPHUS Linné.

Zizyphus lamarensis Berry.

Zizyphus lamarensis Berry, Torrey Bot. Club Bull., vol. 39, p. 398, pl. 31, fig. 1, 1912.

Leaves elliptical in outline, 4.5 to 5 centimeters in length by 3 centimeters in maximum width about midway between the apex and the base, slightly nearer the base. Apex full and rounded, or abruptly and broadly pointed, slightly less full than the base. Margin with regular but shallow crenate teeth, becoming less prominent toward the base. Midrib slender but prominent, straight. Lateral primaries, one on each side, diverging from the midrib at its extreme base at an acute angle (about 10°), thin, slightly curved inward above the middle, joining a secondary in the apical part of the leaf. Two or three alternate thin pairs of secondaries from the midrib in the apical region, camptodrome. Five or six secondaries from the lateral primaries on the outside, curved, camptodrome. The lowest is longest and branches at the most acute angle (about 10°) and from the extreme base. Each successively higher secondary subtends a slightly larger angle and follows a somewhat shorter course. Internal tertiaries more or less percurrent, marginal ones similar to the secondaries from the primaries in their arrangement and course, thin and camptodrome.

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[1] Lesquereux, Leo, The flora of the Dakota group: U. S. Geol. Survey Mon. 17, p. 158, pl. 64, fig. 18, 1892.

[2] Hollick, Arthur, The Cretaceous flora of southern New York and New England; U. S. Geol. Survey Mon. 50, p. 91, pl. 33, fig. 21, 1907.

[3] Velenovsky, Josef, Die flora der böhmischen Kreideformation, pt. 3, p. 6, pl. 7, figs. 1-8, 1884.

[4] Lesquereux, Leo, The Tertiary flora, p. 264, pl. 48, fig. 6, 1878.

This handsome species of an undoubted *Zizyphus* was described recently from the Woodbine sand of Texas, where it is represented by very scanty material. It is entirely distinct from any previously described Cretaceous species and is much closer to some of the Tertiary and still existing forms.

Zizyphus has not yet been discovered in the European Cretaceous, but it is represented in the Western Hemisphere by four or five well-marked types. The one nearest to the present species is *Z. groenlandicus* Heer,[1] which occurs in the Magothy formation on Marthas Vineyard and in the Patoot beds of western Greenland. It is about the same size but relatively wider than the Texas form and has a somewhat different venation and much coarser teeth. The species from the Magothy of New Jersey, *Z. cliffwoodensis* Berry,[2] is a larger, lanceolate entire-margined form. The two species, *Z. elegans* [3] and *Z. oblongus*,[4] described by Hollick from the Cretaceous of Long Island are much smaller, entire-margined forms, and Hollick's *Z. lewisiana* [5] from the same locality and age is a small lanceolate leaf of doubtful affinity.

The existing species of *Zizyphus* number about 40 and are largely indigenous in the Indo-Malayan region, although the genus is represented in subtropical or tropical America, Africa, and Australia. One modern species, *Zizyphus vulgaris* Lamarck, an oriental form, has foliage almost identical with *Z. lamarensis*, the outline, margin, and venation being the same.

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County, Ala.

Collection: U. S. National Museum.

Zizyphus laurifolius Berry.

Zizyphus laurifolius Berry, U. S. Geol. Survey Prof. Paper 84, p. 116, pl. 21, fig. 7, 1914.

This species was recently described by me from the eastern Gulf area, in the work cited, and the discussion need not be repeated here.

Occurrence: Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga.

Collection: U. S. National Museum.

Genus PALIURUS Linné.

Paliurus upatoiensis Berry.

Paliurus upatoiensis Berry, U. S. Geol. Survey Prof. Paper 84, p. 116, pl. 21, figs. 5, 6, 1914.

This species was recently described by me from the eastern Gulf area, in the work cited, and the discussion need not be repeated here.

Occurrence: Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga.

Collection: U. S. National Museum.

Genus EORHAMNIDIUM Berry, n. gen.

Leaves of small size, elliptical to ovate in outline, with entire margins, coriaceous texture, short petioles, and pinnate veins; the secondaries subparallel, ascending, and camptodrome. This genus is erected for a type of leaf that is particularly common in the Mississippi embayment area. It is closely allied to the modern genus *Rhamnidium* Reiss and its recent segregate *Krugiodendron* Urban and is believed to stand in an ancestral relationship to these modern forms. *Rhamnidium* has four species in the Brazilian area and a fifth, *Rhamnidium ferreum* (Vahl) Sargent (*Condalia ferrea* Grisebach), in the Florida Keys, the Bahamas, and the West Indies, which Urban makes the type and only species of *Krugiodendron*. The latter is one of the commonest small trees and is a strictly coastal form.

Eorhamnidium cretaceum Berry, n. sp.

Plate XXVIII, figure 10.

Leaves above the average size for the genus, 3.5 to 4 centimeters in length by 2.8 centimeters in maximum width, which is at a point below the middle. General outline ovate, the base broadly rounded or truncate and the apex bluntly pointed or slightly emarginate. Petiole short and stout. Midrib stout. Secondaries rather stout, about five subopposite to alternate pairs, diverging from the midrib at angles that range from 28° to 47°, slightly curved until they approach the marginal region, where they curve upward, subparallel with the margin and in a camptodrome manner. The margins are entire, and the texture is coriaceous.

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[1] Heer, Oswald, Flora fossilis arctica, vol. 7, p. 42, pl. 62, fig. 20, 1883.

[2] Berry, E. W., Johns Hopkins Univ. Circ., new ser., No. 7, p. 88, fig. 5, 1907.

[3] Hollick, Arthur, Torrey Bot. Club Bull., vol. 21, p. 58, pl. 176, fig. 9, 1894.

[4] Hollick, Arthur, The Cretaceous flora of southern New York and New England: U. S. Geol. Survey Mon. 50, p. 92, pl. 34, figs. 9, 10, 1907.

[5] Hollick, Arthur, Torrey Bot. Club Bull., vol. 21, pl. 180, fig. 13. 1894.

The present species is clearly rhamnaceous, although labeled *Populus* by Ward. Among previously described forms it greatly resembles the single small leaf from the Dakota sandstone that Lesquereux [1] erroneously identified as *Populus stygia* Heer. I am not sure, however, whether or not that form is identical with the present species. *Eorhamnidium cretaceum* is much like some of the leaves of the modern *Krugiodendron ferreum*, a form whose foliage exhibits much minor diversity, and it is also very close to Tertiary forms from the Mississippi embayment area, which are as yet undescribed.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County; Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Eorhamnidium platyphylloides (Lesquereux) Berry, n. comb.

Cornus platyphylloides Lesquereux, The flora of the Dakota group, p. 126, pl. 64, fig. 15, 1892.

The original description of this species, by Lesquereux, which was published in 1892, is as follows:

> Leaves small, thickish, subcoriaceous or membranous, oval, narrowly obtuse and narrowed to the base, entire; median nerve thick; secondaries seven pairs, very oblique, slightly curved in traversing the lamina, parallel, subopposite and subequidistant.

This species was described from the Dakota sandstone of Kansas and referred to the genus *Cornus* because of its great resemblance to *Cornus platyphylla* described by Saporta [2] from the Paleocene of France—a rather remote resemblance, it seems to me.

It is represented in the Tuscaloosa formation by material indistinguishable from the type material, except that it is relatively slightly less elongate. Its reference to *Cornus* was entirely questionable, for it almost certainly represents some genus of the Rhamnaceae.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Genus RHAMNUS Linné.

Rhamnus tenax Lesquereux.

Plate XXV, figures 1, 2.

Rhamnus tenax Lesquereux, Am. Jour. Sci., 2d ser., vol. 46, p. 101, 1868; The Cretaceous flora, p. 109, pl. 21, fig. 4, 1874; The flora of the Dakota group, p. 170, pl. 38, fig. 6, 1892.

Engelhardt, Naturwiss. Gesell. Isis in Dresden Abh. 7, Jahrg. 1891, p. 101, 1892.

Bartsch, Iowa Univ. Lab. Nat. Hist. Bull., vol. 3, p. 181, 1896.

Leaves ovate-lanceolate in outline, acuminate, slightly equilateral. Length about 8 centimeters; maximum width about 2 centimeters in the lower half of the leaf. The dimensions of these leaves are remarkably uniform in all the specimens from the Dakota sandstone of the West, as well as those from the Tuscaloosa formation in Alabama. Margins entire, curving inward somewhat abruptly to the petiole, which is stout, more or less curved, and about 1 centimeter or slightly more in length. Midrib stout, curved, becoming thin in the acuminate tip. Secondaries numerous, thin, approximately parallel, 12 to 14 subopposite to alternate pairs, branching from the midrib at angles of about 45° to 50°, curving slightly upward, camptodrome.

This species, which was described many years ago by Lesquereux from the Dakota sandstone of southern Kansas and subsequently recorded by Bartsch from the same horizon in Iowa, is represented in the lower beds of the Tuscaloosa formation of western Alabama by leaves which are identical in all of their characters with the type material and which seem to be closely allied to the Tertiary and modern forms of *Rhamnus*. It has been reported by Engelhardt from the Cenomanian of Niederschoena, Saxony.

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[1] Lesquereux, Leo, U. S. Geol. Survey Mon. 17, p. 44, pl. 3, fig. 12, 1892.

[2] Saporta, G. de, Prodrome d'une flore fossile des travertins anciens de Sézanne, p. 103, pl. 11, figs. 8, 9, 1868.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Family VITACEAE.

Genus CISSITES Heer.

[Phyllites crétacées du Nebraska, p. 19, 1866.]

Cissites formosus Heer.

Cissites formosus Heer, Flora fossilis arctica, vol. 6, pt. 2, p. 85, pl. 21, figs. 5-8, 1882.
Lesquereux, The flora of the Dakota group, p. 161, pl. 21, fig. 5, 1892.
?Hollick, Torrey Bot. Club Bull., vol. 21, p. 57, pl. 174, fig. 6, 1894; The Cretaceous flora of southern New York and New England, p. 94, pl. 37, fig. 7, 1906.
Newberry, The flora of the Amboy clays, p. 107, pl. 47, figs. 1-8, 1896.
Berry, New Jersey Geol. Survey Bull. 3, p. 185, 1911.

Heer's description, published in 1882, is as follows:

> C. foliis palmatis, profunde trilobatis, lobo medio basi contracto, trilobato, lobis obtusis.

The foregoing description was based upon very fragmentary material from the Atane beds of Greenland, from which, nevertheless, Heer reconstructed the supposed outline of the perfect leaf. To judge by the specimens referred to this species by Lesquereux and Newberry it was an exceedingly variable form. In plan it is trilobate, but the subsidiary lobes developed upon both the median and the lateral lobes in some specimens obscure this trilobate character and suggest *Cissites parvifolius* Berry of the Albian of America and Europe, *Cissites dentatolobatus* Lesquereux of the Dakota sandstone, or *Cissus vitifolia* Velenovsky of the Cenomanian of Bohemia.

The primaries are stout and three in number; they may diverge from the top of the stout petiole or be suprabasilar; in many specimens the branches of the laterals approach so near the base that the leaves have the appearance of being palmately 5-veined.

This species is common but fragmentary in the Raritan formation; it ranges in size from 7 to 10 centimeters in length and from 6 to 12 centimeters between the tips of the main lateral lobes. The sinuses are all rounded, and the main ones may be deep or shallow. The fragment from Long Island referred to this species by Hollick is, as that writer remarks, exceedingly unsatisfactory and doubtful. It occurs also in the Dakota sandstone of Kansas and a closely related variety has been found in the Magothy formation of Maryland.

The genus *Cissites* was erected by Heer in 1866 for the species *Cissites insignis* from the Dakota sandstone of Nebraska, which presented points of affinity with the genus *Cissus* of Linné. It is a largely developed type in the upper half of the Cretaceous period but is replaced after the Eocene by forms which are definitely referable to modern allied genera such as *Cissus* and *Vitis*.

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County, Ala.

Collection: U. S. National Museum.

Cissites crispus Velenovsky.

Cissites crispus Velenovsky, Die flora der böhmischen Kreideformation, pt. 4, p. 12, pl. 4, fig. 6, 1885 (not Newberry, 1896, or Berry, 1911).
Berry, Torrey Bot. Club Bull., vol. 43, p. 296, 1916.

Cissites crispus was identified from the Raritan formation of New Jersey by Newberry and from the Magothy formation of that State by Berry, but neither of these occurrences represents the European form, so that recently I have made them the basis of a new species, *Cissites newberryi*.[1]

A perfectly well characterized, small-leafed form which appears to be identical with the Bohemian type of *Cissites crispus* is, however, present in the Ripley formation of western Tennessee. It differs from *Cissites newberryi* in its relatively shorter and wider form, its crenate instead of serrate or dentate teeth, its less ascending secondaries and its cordate base.

The type and only other known occurrence of *Cissites crispus* is the Chlomeker beds (Emscherian) of Bohemia.

Occurrence: Ripley formation (McNairy sand member), 2½ miles southwest of Selmer, McNairy County, Tenn.

Collection: Johns Hopkins University.

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[1] Berry, E. W., Maryland Geol. Survey, Upper Cretaceous, p. 856, 1916.

Order MALVALES.

Family TILIACEAE.

Genus GREWIOPSIS Saporta.

Grewiopsis formosa Berry, n. sp.

Plate XXV, figures 4, 5.

Leaves relatively large for this genus, more or less trilobate, about 10 centimeters in length by 9 or 10 centimeters in maximum width. Apex bluntly pointed. Base cordate. Lobes more or less developed, ovate conical. Sinuses usually open and shallow. Margin with large dentate teeth or sublobes at ends of secondaries and these finely and evenly denticulate. Petiole stout. Primaries stout, three in number, diverging at or near the base. Laterals form acute angles of about 25° with the midrib. Secondaries numerous, craspedodrome. Tertiaries, with the exception of those which run from the secondaries to the marginal teeth, transverse.

This fine species is usually found in a rather fragmentary condition. It is entirely distinct from previously described species and constitutes one of the earliest records of this genus.

The genus *Grewiopsis* was instituted by Saporta in 1866 for leaves referable to the order Malvales but not positively referable to existing genera. He compared these leaves, which were abundant in the Paleocene of Sézanne, France, with the existing genera, *Sida, Abutilon, Pterospermum, Dombeya, Grewia, Sparmannia, Luhea,* and *Tilia* of this order. They have also been compared with the extinct genus *Credneria* Zenker. About a score of species are known, largely from the early Eocene of Europe and America. Two species are known from the Dakota sandstone, *Grewiopsis aequidentata* and *Grewiopsis flabellata,* both described by Lesquereux. Lesquereux described a third species, *Grewiopsis mudgei,* but this was an unintentional redescription of the type of *Grewiopsis aequidentata. Grewiopsis flabellata* has been recorded from the Magothy formation in the Coastal Plain of Maryland.[1] A third species, *Grewiopsis cleburni,* has been recorded by Lesquereux from the Cretaceous of the Montana group.

Both this and the following Tuscaloosa species are entirely distinct from the foregoing and are more closely allied to certain modern genera of the family Tiliaceae. These are *Grewia* Linné, which has about 90 species, mostly tropical, in the old world; *Hockenya* Willdenow, which has about 15 species in the American Tropics, extending from the Antilles and Central America to Brazil; and *Triumfetta* Linné, with about 60 species in the Tropics of both hemispheres, extending northward in America to the Antilles.

In the deposits of the Mississippi embayment there is a small *Populus*-like species of *Grewiopsis* in the lower Eocene (Wilcox group) and a large and ornate species in the middle Eocene (Claiborne group).

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Grewiopsis tuscaloosensis Berry, n. sp.

Plate XXV, figure 3.

Leaves of small size, elliptical in general outline, about 4 centimeters in length by 3 to 3.5 centimeters in maximum width, which is about halfway between the apex and the base. Apex rounded or bluntly pointed. Base shallowly cordate. Margin dentate throughout; in upper half of the leaf sublobate dentations at ends of the secondaries, which are denticulate to match the teeth lower down. Petiole long, about 2.5 centimeters in length, rather stout. Midrib rather stout. Five or six subopposite pairs of secondaries, branching from the midrib at angles of about 45° or more, craspedodrome. On the outside these give off tertiary branches, which run to the marginal teeth and in turn some of them give off subordinate outside branches to the margin. Balance of the tertiaries transverse, as is the rule in this genus.

This species is much smaller than *Grewiopsis formosa* and altogether lacks the triveined, trilobate character of that species, although the possibility that it may represent an immature or slightly aberrant leaf of that species should not be lost sight of, for it occurs in the same deposits and less abundantly. It is strictly congeneric with the previously described species of *Grewiopsis* and serves to relate the Tuscaloosa formation with the Dakota sandstone as well as to clearly foreshadow the development of this type of vegetation in the early Eocene.

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[1] Berry, E. W., Torrey Bot. Club Bull., vol. 33, p. 177, 1906.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum.

Family STERCULIACEAE.

Genus PTEROSPERMITES Heer.

Pterospermites carolinensis Berry.

Plate XXV, figures 6–8.

Pterospermites carolinensis Berry, Torrey Bot. Club Bull., vol. 34, p. 198, pl. 14, fig. 2, 1907; idem, vol. 43, p. 297, 1916.

Leaves broadly ovate or elliptical in outline. Apex missing but probably broadly pointed. Base broad, ranging from forms in which it is broadly cuneate and slightly decurrent to forms in which it is more or less cordate; in all specimens the lateral margins of the lamina continue downward as wings of the petiole for considerable distances. Length 10 to 15 centimeters (?). Greatest width, 5 to 8 centimeters in the basal half of the leaf. Margins entire, except that they may be somewhat undulate distad. Texture somewhat coriaceous. Petiole very stout, curved, about 2.5 centimeters in length. Midrib straight, rather stout, becoming enlarged to join the petiole. Secondaries subopposite to alternate, rather remote, relatively slender, the lower ones on each side commonly branching from the extreme base of the midrib, giving off at the point of branching a prominent tertiary which makes an angle of about 90° with the midrib and giving off also several tertiaries which arch along the lateral margins; similar marginal camptodrome veins are given off by the basal tertiary just described. The remainder of the secondaries, numbering four or five pairs, diverging from the midrib at angles of about 50°, curving upward, camptodrome. Nervilles thin, largely simple, straight or somewhat curved.

This species was described by the writer in 1907 from the Black Creek formation at Court House Bluff, N. C., where it is not uncommon, although mostly in a poor state of preservation. It appears to be common in the lower part of the Tuscaloosa formation, in western Alabama, where it is also not particularly well preserved, the apical half of the leaf being usually missing. It is present also in the Eutaw formation in Tennessee.

There are three additional species of *Pterospermites* recorded from the American Cretaceous—*P. modestus* Lesquereux of the Dakota sandstone in the West and the upper part of the Raritan formation in the East, *P. obovatus* (Newberry) Berry, of the Raritan formation of New Jersey, and *P. cordifolius* Heer, of the Atane beds of Greenland. During the Eocene there were species in Alaska and Europe, and the genus continued throughout the Tertiary in considerable abundance.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, Fayette County; Cottondale, Tuscaloosa County, Ala. Eutaw formation (Coffee sand member), Coffee Bluff, Hardin County, Tenn.

Collections: U. S. National Museum.

Genus STERCULIA Linné.

Sterculia snowii tennesseensis Berry.

Plate XXXII, figure 1.

Sterculia snowii tennesseensis Berry, Torrey Bot. Club Bull., vol. 43, p. 296, pl. 16, fig. 5, 1916.

Leaf bilobate, with a bluntly pointed base and gradually narrowed acuminate recurved apical lobes. Length about 11 centimeters. Width of the entire basal part of the leaf 2.5 to 2.75 centimeters. Width of lobes 1.1 to 1.6 centimeters. Margins entire. Texture subcoriaceous. Sinus extending halfway to the base or less, open, narrowly rounded. Midrib stout, flexuous. Lateral primary stout, diverging from the midrib at an acute angle about 3 centimeters above its base. Secondaries thin, largely immersed, diverging from the primaries at wide angles and at regular intervals, arching in a camptodrome manner near the margins.

This striking form is unfortunately represented by only two specimens, both of which are bilobate, although it, like so many fossil and existing species of *Sterculia*, may well have varied from entire to trilobate. Among previously described fossil forms it may be compared with the species from the Magothy formation in New Jersey and Maryland, *Sterculia minima* Berry, which is a smaller and more variable form, or with the species from the Dakota sandstone, *Sterculia mucronata* Lesquereux and *Sterculia snowii* Lesquereux. The latter, though often much larger and with five lobes, is extremely variable. Two named varieties of it have already been recognized, and the general character and venation of this Tennessee form leads me to conclude that it represents another variety of this protean species.

Occurrence: Ripley formation (McNairy sand member), 2½ miles southwest of Selmer, McNairy County, Tenn.

Collection: Johns Hopkins University.

Order THYMELEALES.

Family LAURACEAE.

Genus CINNAMOMUM Blume.

Cinnamomum newberryi Berry.

Plate XXI, figures 6-9.

Cinnamomum newberryi Berry, Torrey Bot. Club Bull., vol. 38, p. 423, 1911; New Jersey Geol. Survey Bull. 3, p. 150, pl. 16, fig. 3, 1911.

Cinnamomum sezannense Heer, Flora fossilis arctica, vol. 6, Abt. 2, p. 77, pl. 19, fig. 8; pl. 33, figs. 11, 12, 1882 (not Watelet).

Heer, idem, vol. 7, p. 30, pl. 41, fig. 1a, 1883.

Lesquereux, The flora of the Dakota group, p. 107, pl. 12, fig. 7, 1892 (not fig. 6).

Dawson, Roy. Soc. Canada Trans., 1st ser., vol. 2, sec. 4, p. 64, pl. 13, fig. 58, 1894.

Hollick, Torrey Bot. Club Bull., vol. 21, p. 53, pl. 180, figs. 5, 7, 1894.

Penhallow, Roy. Soc. Canada Trans., 2d ser., vol. 8, sec. 4, p. 46, 1902.

Hollick, New York State Mus. Fifty-fifth Ann. Rept., for 1901, p. r50, 1903.

Cinnamomum intermedium Newberry. Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894 (nomen nudum) (not Ettingshausen).

Newberry, The flora of the Amboy clays, p. 89, pl. 29, figs. 1-8, 1896.

Berry, New Jersey Geol. Survey Ann. Rept. for 1905, p. 139, pl. 20, figs. 2-6, 1906; Torrey Bot. Club Bull., vol. 33, p. 179, pl. 7, figs. 3, 4; idem, vol. 37, p. 27, 1910.

Hollick, The Cretaceous flora of southern New York and New England, p. 74, pl. 29, fig. 7; pl. 30, figs. 1, 2, 1906.

Leaves subcoriaceous, lanceolate to ovate-lanceolate in outline, differing greatly in size and consequently in appearance. Apex short-pointed or more or less narrowly extended; base broad, narrowed to the petiole. Primaries three, usually suprabasilar.

This species is primarily distinguished from *Cinnamomum heerii* Lesquereux by its relatively narrower form and acute base. The present species, as here revised according to the foregoing citations, has a remarkable range in the earlier half of the Upper Cretaceous, being recorded from the Raritan formation of New Jersey, which is the oldest horizon from which it is known. Above the Raritan horizon it occurs in the Atane and Patoot beds of Greenland, in the Magothy formation from Long Island to Maryland, in the Black Creek formation of North Carolina, in the Middendorf arkose member of the Black Creek formation of South Carolina, in the Tuscaloosa formation of Georgia and Alabama, and in the Dakota sandstone of Kansas. It appears to be present in the Upper Cretaceous of the Pacific coast on Vancouver Island and is probably represented in the Texas remains of *Cinnamomum* recorded by Knowlton[1] from the Woodbine sand in Cooke County. Although not known from Europe the forms from the Cenomanian of Bohemia which Velenovsky describes as *Aralia daphnophyllum*[2] are very similar to the American species.

Occurrence: Tuscaloosa formation, Shirleys Mill, Glen Allen, Fayette County; Cottondale, Tuscaloosa County, Ala. Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga.

Collections: U. S. National Museum.

Cinnamomum heerii Lesquereux (?).

Cinnamomum heerii Lesquereux, Am. Jour. Sci., 2d ser., vol. 27, p. 361, 1859.

Berry, U. S. Geol. Survey Prof. Paper 84, p. 118, pl. 21, fig. 8, 1914; Torrey Bot. Club Bull., vol. 43, p. 298, 1916.

This species in the eastern Gulf area was recently discussed by me in the paper cited.

Occurrence: Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga.; (Coffee sand member), Coffee Bluff, Hardin County, Tenn.

Collections: U. S. National Museum.

Cinnamomum sp.

Cinnamomum sp. Berry, Torrey Bot. Club Bull., vol. 43, p. 299, 1916.

A characteristic *Cinnamomum*, apparently distinct from *Cinnamomum newberryi* and *Cinnamomum heerii*, the two most common and wide-ranging Upper Cretaceous species, is present in the Ripley formation. The material is too imperfect for satisfactory characterization.

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[1] Knowlton, F. H., in Hill, R. T., U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 317, 1901.

[2] Velenovsky, Josef, Die Flora der böhmischen Kreideformation, Theil 1, p. 23, pl. 5, figs. 5-8, 10; pl. 6, figs. 1-5, 1882.

Occurrence: Ripley formation (McNairy sand member), 2½ miles southwest of Selmer, McNairy County, Tenn.

Collection: Johns Hopkins University.

Genus PERSEA Gaertner.

Persea valida Hollick.

Plate XXI, figure 2.

Persea valida Hollick, The Cretaceous flora of southern New York and New England, p. 76, pl. 29, figs. 8, 9, 1906.

Leaves ovate-lanceolate in outline, with slightly waved margins, 9 to 11 centimeters in length by about 3 centimeters in maximum width, which is about halfway between the apex and the base. Apex somewhat abruptly acuminate. Base about equally sharp, cuneate. Petiole short and stout. Midrib stout, curved, and somewhat flexuous distad. Secondaries numerous, thin, 9 to 12 pairs, somewhat irregularly spaced and branching from the midrib at mostly acute angles, curving upward, camptodrome.

This well-marked species was recently described by Hollick from the Upper Cretaceous of Long Island. The Tuscaloosa leaves are identical in character with the type material, the specimen figured from Cottondale, Ala., being an almost exact counterpart of the smaller of Hollick's figures.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Genus OREODAPHNE Nees and Martius.

Oreodaphne shirleyensis Berry, n. sp.

Plate XIX, figures 1, 2.

Leaves of medium size, broadly ovate in outline, with an acuminate apex and a broadly rounded base, about 10 centimeters in length by 4.5 centimeters in maximum width, which is in the middle part of the leaf. From this point the margins are full and curved to the base. Distad they curve outward then inward, narrowing more or less gradually to the narrowly pointed apex. Midrib stout, curved. Secondaries about six pairs. The second pair from the base branch from the midrib at a somewhat more acute angle than those above or below. They are also somewhat stouter, straighter, and more ascending, although much thinner than the midrib. They are alternate and have the appearance of lateral primaries, giving the leaf somewhat the appearance of a triveined leaf, but they are really only slightly enlarged secondaries. All the secondaries are camptodrome.

This species is new to science and is clearly distinct from *Oreodaphne alabamensis* in size, outline, and general appearance. The base is quite different, and the development of a normal pair of secondaries below the alternate pseudoprimaries instead of the numerous parallel secondaries from the outer side of the true primaries, which are so conspicuous a feature in *Oreodaphne alabamensis*, affords a ready means of discrimination between the two species.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Oreodaphne alabamensis Berry.

Plate XIX, figures 3-5.

Oreodaphne alabamensis Berry, Torrey Bot. Club Bull., vol. 39, p. 400, pl. 32, 1912.

Leaves of large size, ovate in general outline, ranging from 13 to 20 centimeters in length, and from 4.75 to 7 centimeters in maximum width, which is at a point about midway between the apex and the base. From the point of greatest width the margins extend, both distad and proximad, in a very full curve, narrowing rather abruptly to the acuminate tip and also to the more or less decurrent base. Midrib stout, curved. Lateral primaries opposite, one on each side, branching from the midrib at an acute angle a considerable distance above its base, rather straight in their course, thinner than the midrib. Above the primaries there is an interval and then about six pairs of thin, curved, approximately parallel, camptodrome secondaries branch from the midrib at acute angles. The lateral primaries give off on the outside numerous regularly spaced and approximately parallel, curved camptodrome secondaries, this feature serving to distinguish this species from other fossil species of this genus, and from *Cinnamomum*, *Cocculus*, or other genera with somewhat similar leaves with which it might be compared. Texture coriaceous.

This fine, large species shows considerable variation in size and some in outline, the variation in outline being dependent on whether the leaf is widest nearer to or farther from the base. If the leaf is widest farther from the base the distal part is more fully rounded and abruptly contracted to the acuminate tip, whereas the base is more gradually narrowed and finally cuneate rather than decurrent. If the greatest width is nearer the base the apical portion is more gradually narrowed and the base is full and rounded abruptly, decurring to the petiole. It is also present in the Woodbine sand at Arthurs Bluff, Lamar County, Tex.

This species is markedly different from previously described fossil forms but may be matched by several modern tropical American species of *Oreodaphne*. The genus *Oreodaphne* of Nees, which is exclusively American in the existing flora, is made a subgenus of *Ocotea* Aublet by Pax.[1] Ocotea, which in paleobotanic usage may be considered as composite, has about 200 modern species, which occur chiefly in the American Tropics and range from southern Florida to Brazil and Peru but have some representation (subgenus *Mespilodaphne* Nees) in the Canary Islands, South Africa, Madagascar, and the Mascarene Islands.

Our single existing species in the United States, whose habit and environment may be taken as typical for the whole genus, is found in Florida southward from Capes Canaveral and Romano along the shores and islands, with the exception of some of the western keys, making its best growth in the rich, moist, hammock lands near the coast.

The genus is abundantly represented by several characteristic species in the Eocene floras of the Gulf region.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Genus SASSAFRAS Nees.

[Handbuch der medizinisch-pharmaceutischen Botanik, vol. 2, p. 418, 1831.]

Sassafras acutilobum Lesquereux.

Sassafras acutilobum Lesquereux, The Cretaceous flora, p. 79, pl. 14, figs. 1, 2, 1874; The Cretaceous and Tertiary floras, p. 56, pl. 5, figs. 1, 5, 1883; The flora of the Dakota group, p. 100, 1892.

Hollick, New York Acad. Sci. Trans., vol. 12, p. 236, pl. 7, fig. 1, 1893; The Cretaceous flora of southern New York and New England, p. 77, pl. 30, figs. 8, 9, 1906.

Newberry, The flora of the Amboy clays, p. 87, pl. 25, figs. 1–10; pl. 26, figs. 2–6, 1896.

Kurtz, Rev. Mus. La Plata, vol. 10, p. 53, 1902.

Berry, Bot. Gazette, vol. 34, p. 438, 1902; New York Bot. Garden Bull., vol. 3, p. 81, pl. 45, figs. 1, 2, 1903; Torrey, Bot. Club Bull., vol. 31, pl. 1, fig. 6, 1904; New Jersey Geol. Survey Ann. Rept. for 1905, p. 139, pl. 22, figs. 4, 5, 1906; New Jersey Geol. Survey Bull. 3, p. 140, pl. 18, fig. 2, 1911.

Trilobate leaves, variable in size and outline. Length ranges from 2.5 centimeters in the young leaves to 14 centimeters in mature forms and averages 10 to 12 centimeters. Width from the tips of the lateral lobes likewise ranges from 1 to 15 centimeters averaging about 10 centimeters. Lobes mostly conical and acute, the middle one being usually slightly the broadest and longest. Lateral lobes directed more or less laterally. Base decurrent. The sinuses between the lobes as a rule are open and rounded, the margins forming an angle of approximately 90°. There is considerable variation, however, in this respect, some of the leaves having comparatively narrow sinuses with the lobes directed upward, as in *Sassafras progenitor* Hollick, whereas others, at the opposite extreme of the series, have extremely shallow sinuses, so shallow that the leaf has the appearance of a triangularly pointed, entire leaf. The lateral primaries may branch from the midrib at or near the base, as they do in a majority of the Raritan forms, or their point of divergence may be a considerable distance above the base, as in modern *Sassafras* leaves. Their angle of divergence from the midrib ranges from about 30° to 40°. The secondaries are usually numerous, regular, camptodrome, and connected by transverse tertiaries, although in the Raritan leaves this uniformity is often lacking. Petiole, long and stout. The marginal vein along the sinus, a marked feature in modern leaves of this genus, is generally absent in this species, although present in a few specimens.

This species is apparently widely distributed and almost as variable as the modern *Sassafras*. It was described originally from the Dakota sandstone as a variety of *Sassafras mudgei* and occurs also on Marthas Vineyard and Long Island and in the Raritan and Magothy formations of New Jersey and Delaware. It has been recorded from Cerro Guido, Argentina, and Velenovsky identified somewhat doubtful remains from the Cenomanian of Bohemia as this species. Probable *Sassafras* fruit has been found in the same strata with *S. acutilobum*,[1] tending to show that it is a true *Sassafras*, notwithstanding its dissimilarities; however, the leaves and fruit were not found associated. Lesquereux's smallest figure of *S. acutilobum* is considerably smaller, with the lobes directed upward, and is probably a young leaf of his larger form. His other figure approaches some of the leaves which Newberry refers to this species but has narrower and more produced lobes.

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[1] Engler, A., and Prantl, K., Die natürlichen Pflanzenfamilie.

There is considerable doubt as to whether these Coastal Plain leaves are generically related to *Sassafras*. Whether the Dakota sandstone forms are those of *Sassafras* it is not easy to decide. No modern *Sassafras* leaves have the primaries and the lateral lobes so nearly horizontal; the secondaries are not so uniformly regular, nor do they curve upward to join the next above at a point. In the modern leaf an outwardly and downwardly directed branch from the lateral lobe is emphasized. None of the modern forms have such an open sinus, which amounts in the fossil to nearly 90°, and the lobes in the modern leaf have their margins inflated and not straight. In these ancient leaves the sinus as a rule does not have a marginal vein, the secondary in this region usually forking and striding it, or curving to join its neighbor. The secondary system seems to be uniform throughout the leaf, but in the modern leaf there is always evidence of changes in the region around the sinus; the secondaries or their representatives from both the primaries and midrib are changed in size and direction, and as a rule belong to the tertiary system. None of the Dakota leaves of this species show the characteristic basal venation of the modern leaf. Though Cretaceous species should not necessarily be expected to conform to the modern type, still the character of the secondary system in the fossils is so different from what would obtain in a leaf descended from a simple ancestor, such as *Sassafras* is thought to have done, that I am inclined to associate these leaves with those trilobed forms which have been referred to *Aralia* or *Sterculia*, laying aside, for the present, any consideration as to whether they are true species of *Aralia* and *Sterculia*. However, in view of the present uncertainty, and because of the havoc to the stratigraphic value of these leaves which would be wrought by any change of name, they are retained in the genus *Sassafras* pending more positive evidence of their affinity.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Genus MALAPOENNA Nees.

Malapoenna cottondalensis Berry, n. sp.

Plate XXI, figure 4.

Leaves lanceolate in general outline, 11 to 12 centimeters in length by about 2.5 centimeters in maximum width in the basal half of the leaf. Apex gradually narrowed, acuminate. Base curved cuneate, pointed. Midrib stout, becoming thin distad. Secondaries about eight to ten pairs; the lowest pair are opposite and suprabasilar, diverging from the midrib at angles of about 25°, ascending for a distance of about 4 centimeters to a point where they join an outwardly directed branch from the secondaries next above, thus giving the basal part of the leaf a triveined appearance; after an interval the remaining secondaries are more or less equally spaced, approximately parallel and alternate, branching from the midrib at angles of about 40° to 45°, regularly curved upward and camptodrome.

This species, which is obviously new, is much larger than *Malapoenna falcifolia*. It is about the same size as *Malapoenna cretacea* but narrower and more elongated and attenuated above. The secondaries are thinner and only one pair extended to simulate primaries.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Malapoenna cretacea (Lesquereux) Knowlton.

Plate XXI, figure 3.

Litsea cretacea Lesquereux, The flora of the Dakota group, p. 96, pl. 15, fig. 2, 1892.

Malapoenna cretacea (Lesquereux) Knowlton, U. S. Geol. Survey Bull. 152, p. 142, 1898.

Leaves oblong-lanceolate in outline with a cuneate or slightly decurrent base, widest in the lower half of the leaf and tapering upward into an acuminate apex. Length 10 to 14 centimeters. Maximum width about 3 centimeters. Margins entire but slightly waved. Texture coriaceous. Petiole short and stout. Midrib stout. Secondaries thin, five or six pairs, irregularly spaced; proximad they branch from the midrib at acute angles and sweep upward in long, ascending curves, which give these leaves the semblance of being triveined; distad they branch at a wider angle and are shorter and more curved; all are finally camptodrome.

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[1] Lesquereux, Leo, The flora of the Dakota group: U. S. Geol. Survey Mon. 17, p. 230, 1892.

This handsome species, which was originally described from the Dakota sandstone of Kansas, to which it has hitherto been confined, is unmistakably present in the lower part of the Tuscaloosa formation of western Alabama.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Malapoenna falcifolia (Lesquereux) Knowlton.

Plate XXI, figure 5.

Litsea falcifolia Lesquereux, The flora of the Dakota group, p. 97, pl. 11, fig. 5, 1892.

Malapoenna falcifolia (Lesquereux) Knowlton, U. S. Geol. Survey Bull. 152, p. 142, 1898.

Berry, Torrey Bot. Club Bull., vol. 33, p. 180, 1906. New Jersey Geol. Survey Ann. Rept. for 1905, p. 139, 1906.

Leaves of relatively small size, lanceolate in outline, falcate. Length about 5 to 6 centimeters. Maximum width, which is about halfway between the apex and the base, if anything slightly nearer the base, about 1.7 centimeters. From this point the blade narrows to the lanceolate base and gradually tapers to the extended acuminate tip. Petiole not preserved. Midrib much curved, thin distad. Secondaries three or four pairs; the lower suprabasilar and subopposite pair should possibly be termed lateral primaries, as was done by the original describer of the species. These lower secondaries are thin and branch from the midrib at angles of 45° or less, sweeping upward in a long curve, at length camptodrome. Upper secondaries somewhat irregularly spaced, camptodrome. Tertiaries very fine and more or less obsolete. Texture coriaceous but not thick.

This attractive species is easily distinguished from other lauraceous forms, particularly from species of *Cinnamomum*, with which Lesquereux originally compared it, by its slight inequilaterality and marked falcate form, as well as by the lack of definiteness in the triple venation, the suprabasilar position of the so-called primaries, and the character of the tertiary venation. It was described originally from the Dakota sandstone of Kansas and subsequently was discovered by the writer in the Magothy formation of New Jersey. Some of the specimens from the lower part of the Tuscaloosa formation, though the materials are not extensive, are complete and are entirely characteristic.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Malapoenna horrellensis Berry.

Malapoenna horrellensis Berry, Torrey Bot. Club Bull., vol. 37, p. 198, pl. 24, figs. 1–9, 1910. Idem, vol. 43, p. 299, 1916.

I described this species in 1910 as follows:

> Leaves ovate-lanceolate, about 8 centimeters long by 2.5 centimeters in greatest width; broadest at the evenly rounded or slightly acute base, narrowing gradually upward, the apex narrow and extended but obtusely pointed. Leaf substance thin but persistent, evidently coriaceous in life, since these leaves occur abundantly at a locality where all the vegetable remains except the resistant *Araucaria*, *Cunninghamites*, and *Pistia* were evidently thoroughly macerated before entombment. Secondaries 4 to 6 pairs, subopposite, curved upward, camptodrome, branching from the midrib at an acute angle, the lowest pair branching from the top of the petiole and extending upward halfway to the apex or farther, giving the leaf a triple-veined appearance. Perhaps they should be termed lateral primaries, although they are much finer than the medium stout midrib. The next pair of secondaries branch at a less acute angle a considerable distance above the base, one-third to one-half the distance to the apex. Tertiary venation typically lauraceous.

This species is markedly distinct from the species of lauraceous leaves hitherto described in its rounded base, the only genus of this family with such a character being *Cinnamomum*, the present species being possibly liable to be confused with *Cinnamomum heeri* Lesquereux when only the basal part of the leaf is found. The general proportions and characters of the whole leaf are, however, perfectly distinct.

It was described from several localities in the upper part of the Black Creek formation of North Carolina and is represented in the collections from the basal part of the Eutaw formation of Alabama from Hale County. It is also present in the basal beds of the Eutaw in western Georgia.

Occurrence: Eutaw formation, Havana, Hale County, Ala.; Broken Arrow Bend, Chattahoochee County, Ga. Ripley formation (McNairy sand member), Big Cut near Cypress and 2½ miles southwest of Selmer, McNairy County, Tenn.

Collection: U. S. National Museum.

Genus LAURUS Linné.

Laurus plutonia Heer.

Laurus plutonia Heer, Flora fossiles arctica, vol. 6, abt. 2, p. 75, pl. 19, figs. 1d, 2-4; pl. 20, figs. 3a, 4-5; pl. 28, figs. 10, 11; pl. 42, fig. 4b, 1882; idem, vol. 7, p. 30, pl. 48, fig. 2; pl. 62, fig. 1a, 1883.

Lesquereux, The flora of the Dakota group, p. 91, pl. 13, figs. 5, 6; pl. 22, fig. 5, 1892; Minnesota Geol. and Nat. Hist. Survey, vol. 3, pt. 1, p. 14, pl. A, fig. 6; pl. B, fig. 5, 1895.

Newberry, The flora of the Amboy clays, p. 85, pl. 16, figs. 10, 11, 1896.

Velenovsky, Die flora der böhmischen Kreideformation, Theil 3, p. 1, pl. 4, figs. 2-4, 1884.

Hollick, New York Acad. Sci. Ann., vol. 40, p. 60, pl. 4, figs. 6, 7, 1898; The Cretaceous flora of southern New York and New England, p. 80, pl. 27, figs. 9, 11; pl. 28, figs. 1, 2, 1906.

Berry, New York Bot. Garden Bull., vol. 3, p. 79, pl. 1, figs. 9-11, 1903; Torrey Bot. Club Bull., vol. 31, p. 77, pl. 3, fig. 1, 1904; idem, vol. 33, p. 173, 1906; New Jersey Geol. Survey Ann. Rept. for 1905, pp. 138, 139, 1906; New Jersey Geol. Survey Bull. 3, p. 144, 1911.

Leaves lanceolate in outline, usually tapering almost equally in both directions but sometimes less acute at the base. Length, 7 to 11 centimeters. Maximum width, 1.5 to 2.5 centimeters. Midrib rather stout. Petiole short and stout, 6 to 15 millimeters in length. Secondaries slender, eight or more alternate pairs, camptodrome.

This species was described by Heer from the Atane beds of Greenland, and a large number of somewhat variable and fragmentary specimens were figured. Newberry records specimens from the Raritan formation of New Jersey without giving any specific localities. Those figured show leaves which are relatively wider than the usual leaves of this species, but these are comparable with some of the Greenland specimens.[1] Entire typical leaves occur in the top layer of the Raritan at the Hylton Pits near Camden, N. J.

Subsequent to its description by Heer, this species was recorded from a very large number of Cretaceous plant beds, so that its present range, both geographic and geologic, is rather wide. Many of these records are not entirely above question, and this appears to be especially true of the forms from the Cenomanian of Bohemia which Velenovsky so identifies.

Laurus plutonia is evidently a rare plant in the Raritan formation but becomes abundant in immediately succeeding floras, being common in that of the Dakota sandstone of the West and in the Magothy formation of the East at a number of localities in New Jersey and Maryland. It is a common form in the insular Cretaceous floras and also occurs in the southern Atlantic Coastal Plain. Supposed fruits are figured by Heer.[2] In South Carolina this species is represented by typical leaves which are not at all uncommon in the Middendorf arkose member of the Black Creek formation. It has not been detected in the North Carolina Cretaceous, although it ranges from the base to the top of the Tuscaloosa formation and into the base of the Eutaw formation in Alabama.

The generic name *Laurus* is used as a form genus for fossil Lauraceae, and its use does not imply an intimate relationship with the existing species of *Laurus*. The present form is probably not a true *Laurus* but is referable to *Oreodaphne*, *Mespilodaphne*, or *Nectandra*.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; Cottondale, Tuscaloosa County, Ala. Eutaw formation (basal beds), 2 miles south of Havana, Hale County, Ala.

Collections: U. S. National Museum.

Genus LAUROPHYLLUM Goeppert.

Laurophyllum nervillosum Hollick.

Plate XXI, figure 1.

Laurophyllum nervillosum Hollick, The Cretaceous flora of southern New York and New England, p. 82, pl. 27, figs. 6, 7, 1906.

Berry, Torrey Bot. Club Bull., vol. 36, p. 255, 1909. New Jersey Geol. Survey Bull. 3, p. 146, 1911.

Proteoides daphnogenoides Heer. Hollick, New York Acad. Sci. Ann., vol. 2, p. 420, pl. 36, figs. 1, 3, 1898.

Leaves of comparatively large size, oblong-lanceolate in outline, somewhat inequilateral in some of the Tuscaloosa material, about 15 centimeters in length by about 2.5 centimeters in greatest width, which is about midway between the apex and the base. Apex acuminate. Base pointed, narrowly cuneate. Midrib stout. Secondaries thin, close, parallel, branching from the midrib at angles not exceeding and usually somewhat less than 45°, ascending, nearly straight or somewhat flexuous, connected by transverse nervilles, branching and inosculating near the margin, where they merge in the tertiary venation.

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[1] Heer, Oswald, Flora fossilis arctica, vol. 6, Abt. 2, pl. 20, fig. 5; pl. 28, fig. 11, 1882.

[2] Idem, pl. 42, fig. 4b.

This species was described originally from the transported morainic material at Tottenville, Staten Island, and probably represents transported Raritan materials, as it occurs in the Raritan formation at Milltown, N. J. It is, however, present in the succeeding Magothy formation and is not uncommon in the typical Black Creek formation of the Carolinas and in the Middendorf arkose member of the Black Creek formation in South Carolina. It is somewhat like *Laurophyllum lanceolatum* Newberry but has a markedly different venation and a less lanceolate outline. It is also very close to *Laurophyllum elegans* Hollick, which is, however, a more slender lanceolate leaf, with narrowly produced apex and base and a somewhat coarser venation, with less close and more curved camptodrome secondaries.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Laurophyllum angustifolium Newberry.

Laurophyllum angustifolium Newberry, The flora of the Amboy clays, p. 86, pl. 17, figs. 10, 11, 1896.

Berry, New York Bot. Garden Bull., vol. 3, p. 80, pl. 47, figs. 1, 5, 8; pl. 49, figs. 1–5, 1903; Torrey Bot. Club Bull., vol. 33, p. 178, 1906; New Jersey Geol. Survey Bull. 3, p. 148, 1911.

Leaves elongate-lanceolate, very symmetric in outline, 10 to 15 centimeters in length, by 1.5 to 2 centimeters in width, widest above the middle, tapering with almost straight sides to the elongate-acute base. Apex narrowed, subacute. Petiole short and stout. Midrib also stout. Secondaries fine, commonly obsolete, 12 to 15 pairs, branching from the midrib at an angle of about 45° and curving upward camptodrome. Texture subcoriaceous.

This species, which was described from the middle part of the Raritan formation of New Jersey, where it is common, has also been found in the overlying Magothy formation in both New Jersey and Maryland. In the absence of complete and well-marked specimens many of those available can with difficulty be differentiated from contemporaneous species of other genera with similar lanceolate leaves.

Occurrence: Tuscaloosa formation, upper ravine on the Snow place, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Laurophyllum elegans Hollick.

Laurophyllum elegans Hollick, The Cretaceous flora of southern New York and New England, p. 81, pl. 27, figs. 1–5, 1907.

Berry, U. S. Geol. Survey Prof. Paper 84, p. 53, pl. 12, fig. 6, 1914; Torrey Bot. Club Bull., vol. 43, p. 297, 1916.

Leaves elongate-lanceolate, somewhat flexuous, about 12 or 13 centimeters in length by about 2 centimeters in maximum width, which is about midway between the apex and the base; from this point they narrow gradually apicad into an attenuated acuminate and usually curved tip and basally into a long, narrowly cuneate base. Petiole and midrib stout. Secondaries numerous, usually less close and somewhat coarser than in *Laurophyllum nervillosum* Hollick, branching from the midrib at acute angles below but becoming more open above the basal region of the leaf; they are usually more curved than those of *Laurophyllum nervillosum* and more distinctly camptodrome. Tertiaries transverse throughout.

This species is certainly present in the upper beds of the Raritan formation at South Amboy, N. J., and is common in the Magothy formation of Maryland. It is sparingly represented in the Black Creek formation of North Carolina and in the Middendorf arkose member of the Black Creek formation of South Carolina.

Occurrence: Eutaw formation (Coffee sand member), Coffee Bluff, Hardin County, Tenn.

Collection: Johns Hopkins University.

Order MYRTALES.

Family MYRTACEAE.

Genus EUGENIA Linné.

Eugenia tuscaloosensis Berry, n. sp.

Plate XXVIII, figure 6.

Leaves of small size, lanceolate in outline, falcate, slightly inequilateral. Length ranging from 5 to 8 centimeters. Maximum width, which is in the lower half of the leaf, 1 to 1.3 centimeters; from this point the leaf tapers gradually upward into a long, attenuated tip, forming a "dripping point." Base narrowly cuneate. Margins entire. Petiole very stout and curved, about 7 millimeters in length. Midrib stout below, thinning distad, curved. Secondaries numerous, thin, ascending; they branch from the midrib at an acute angle, which is invariably less than 45°, and are straight at first, afterward curving upward, camptodrome. Texture coriaceous.

Eugenia, which is a genus that contains more than 500 existing species, is commonly represented in all tropical countries. Five species, of which four are small trees, reach as far northward as southern Florida and the Bahamas. They are all coastal types, growing on the keys, where they commonly form the "scrub" on coral rock, or in rich hammocks where the water table is near the surface, or on river or estuary banks near the coast.

The number of fossil species which have been described is inconsiderable. The present species is the first to be recognized in the Coastal Plain. A very different form, *Eugenia primaeva*, has been described from the Dakota sandstone by Lesquereux.[1] With the exception of these two the remainder of the species, numbering less than a dozen, are Tertiary in age and confined to Europe, although the genus is known to be present in the Eocene deposits of the Mississippi embayment.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Eugenia? anceps Berry.

Plate XXXII, figures 3-5.

Eugenia? anceps Berry, Torrey Bot. Club Bull., vol. 43, p. 301, pl. 16, figs. 2-4, 1916.

Coriaceous leaves of variable size and form, lanceolate or oblong-lanceolate in outline. Apex and base equally acuminate or the apex somewhat more attenuated. Margins entire. Length 7.75 to 10 centimeters. Maximum width, midway between the apex and the base, 11 to 18 millimeters. Petiole enlarged, short and stout, 3 to 4 millimeters in length. Midrib stout. Secondaries thin, immersed in the leaf substance.

This species is referred to *Eugenia* with considerable hesitation. The material is abundant but poorly preserved, and these leaves resemble a variety of forms referred to such genera as *Salix* and *Laurophyllum*.

Eugenia has furnished a species in the Tuscaloosa formation of Alabama, another in the Dakota sandstone of the western United States, and is not uncommon in the Eocene of the Mississippi embayment region.

Occurrence: Ripley formation (McNairy sand member), 2½ miles southwest of Selmer, McNairy County, Tenn.

Collection: Johns Hopkins University.

Genus MYRCIA De Candolle.

Myrcia havanensis Berry.

Plate XI, figure 4; Plate XXVIII, figure 7.

Myrcia havanensis Berry, Torrey Bot. Club Bull., vol. 43, p. 300, 1916.

Eucalyptus attenuata Ward (not Newberry), U. S. Geol. Survey Fifteenth Ann. Rept., p. 371, 1895.

Leaves linear-lanceolate in outline, falcate, about 9 centimeters in length by 1 centimeter in maximum width, which is in the lower half of the leaf. Margins entire. Apex gradually narrowed, acuminate. Base narrowly pointed, decurrent. Petiole very stout, tapering upward, 1.75 centimeters in length. Midrib stout, curved. Secondaries numerous, thin, somewhat irregularly spaced, 2 to 6 millimeters apart, branching from the midrib at angles of about 40°, running with but slight curvature to the well-marked and nearly straight longitudinal vein which forms a marginal hem less than 0.5 millimeter from the margin. Texture coriaceous.

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[1] Lesquereux, Leo, U. S. Geol. Survey Mon. 17, p. 137, pl. 53, figs. 5-9, 1892.

The present species is very close to some of the numerous forms which from time to time have been referred to *Eucalyptus geinitzi* (Heer) Heer. It is, however, distinct from that species, especially when compared with Heer's type or with the more typical American material. In general it is a smaller leaf, has a larger and longer petiole and an outline less inclined toward ovate, and is relatively much more produced apically. It is typically *Myrcia*-like in all of its characters and is readily distinguishable from the forms from the Tuscaloosa formation which have been referred to *Eucalyptus geinitzi* in this work. It is confined to the basal beds of the Eutaw formation in Hale County, Ala., and the Ripley formation in western Tennessee, and takes its name from the town of Havana, near which the leaf-bearing laminated clays of this formation outcrop. A single specimen collected by R. T. Hill in 1891 at the big cut on the Southern Railway east of Pocahontas, Tenn., and identified by Ward as *Eucalyptus attenuata* Newberry, proves to belong to this species.

Occurrence: Eutaw formation (basal beds), 2 miles south of Havana, Hale County, Ala. Ripley formation (McNairy sand member), Camden-Paris road, 13 miles northwest of Camden, Benton County; big cut 1½ miles west of Cypress, 2½ miles southwest of Selmer, McNairy County, Tenn.

Collections: U. S. National Museum.

Genus EUCALYPTUS L'Héritier.

Eucalyptus latifolia Hollick.

Eucalyptus latifolia Hollick, The Cretaceous flora of southern New York and New England, p. 97, pl. 36, figs. 1-5, 1906.
Berry, Torrey Bot. Club Bull., vol. 37, p. 26, 1910.

Leaves elongate-ovate in outline, tapering to a somewhat abruptly attenuated and more or less curved or flexuous tip. Base cuneate. Length about 15 centimeters. Maximum width, about halfway between the apex and the base, about 5 centimeters. Midrib stout, flexuous. Secondaries thin, numerous, diverging from the midrib at angles of 45° to 50°, nearly straight or flexuous, their tips joined by a marginal vein. Margins entire. Texture subcoriaceous.

These large leaves occur in the Magothy formation of Marthas Vineyard, Long Island, and Maryland. They are not uncommon at a single locality in the lower part of the Tuscaloosa formation. Their relation to *Eucalyptus* is extremely doubtful, but a change of generic reference is not considered advisable at the present time. According to long-established usage, therefore, this species and *Eucalyptus geinitzi* and *E. angusta* are referred to the genus *Eucalyptus*, although it seems more probable that they represent the genus *Myrcia* of this same family, or its ancestral stock.

Occurrence: Tuscaloosa formation, upper ravine on the Snow place, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Eucalyptus geinitzi (Heer) Heer.

Plate XXVIII, figure 8.

Myrtophyllum geinitzi Heer, Flora von Moletein in Mähren, p. 22, pl. 11, figs. 3, 4, 1872; Flora fossilis arctica, vol. 3, Abt. 2, p. 116, pl. 32, figs. 14-17, 1874.
Eucalyptus geinitzi (Heer) Heer, Flora fossilis arctica, vol. 6, Abt. 2, p. 93, pl. 19, fig. 1c; pl. 4, figs. 1, 13, 1885.
Engelhardt, Naturwiss. Gesell. Isis in Dresden Abh. 7, Jahrg. 1891, p. 102, 1892.
Lesquereux, The flora of the Dakota group, p. 138, pl. 37, fig. 20, 1892.
Newberry, The flora of the Amboy clays, p. 110, pl. 32, figs. 2, 12 (not figs. 15, 16), 1896.
Hollick, New York Acad. Sci. Ann., vol. 11, p. 60, pl. 4, figs. 1-3, 1898; The Cretaceous flora of southern New York and New England, p. 96, pl. 35, figs. 1-8, 10-12, 1906.
Berry, New York Bot. Garden Bull., vol. 3, p. 87, pl. 53, fig. 3, 1903; Torrey Bot. Club Bull., vol. 31, p. 78, pl. 4, fig. 5, 1904; idem, vol. 33, p. 180, 1906; idem, vol. 34, p. 201, pl. 15, fig. 4, 1907; Johns Hopkins Univ. Circ. new ser., No. 7, p. 81, 1907; New Jersey Geol. Survey Bull. 3, p. 189, pl. 28, fig. 7, 1911.
Myrtophyllum warderi Lesquereux, The flora of the Dakota group, p. 136, pl. 53, fig. 10, 1892.
Hollick, The Cretaceous flora of southern New York and New England, p. 97, pl. 35, fig. 13, 1906.
Eucalyptus? angustifolia Newberry, The flora of the Amboy clays (not Desvaux, 1822), p. 111, pl. 32, figs. 1, 6, 7, 1896.
Hollick, New York Bot. Garden Bull., vol. 3, p. 408, pl. 70, figs. 8, 9, 1904; The Cretaceous flora of southern New York and New England, p. 95, pl. 35, figs. 9, 14, 15, 1906.
Berry, New Jersey Geol. Survey Bull. 3, pl. 28, fig. 5, 1911.

Leaves lanceolate in outline, broadest near the middle and tapering almost equally in both directions to the acute apex and base. There is considerable variation in size, the South Carolina leaves averaging about 15 centimeters in length by 2.2 centimeters in greatest width. The petiole is very stout, as is the prominent midrib, which leaves a sharp groove in impressions showing the lower surface. Secondaries numerous, thin, branching from the midrib at angles of about 45° and running with but a slight curvature to the marginal vein, which is either almost straight when the secondaries are close set or more or less bowed when the secondaries are some little distance apart, as they are in many specimens.

This species has a wide range. It was described originally from the Cenomanian of Moravia and has since been recorded from a number of other European Cenomanian localities, from the Atane beds of Greenland, the Dakota sandstone of the West, and from Marthas Vineyard to Alabama along the Atlantic coast. It ranges upward into the Black Creek formation of North Carolina and is not rare in the Middendorf arkose member of the Black Creek formation of South Carolina. In Alabama the species is not common, but this may simply be due to accidents of preservation.

Occurrence: Tuscaloosa formation, upper ravine and big gully on the Snow place, Tuscaloosa County; roadside southwest of Northport, Tuscaloosa County; near Maplesville, Chilton County, Ala.

Collection: U. S. National Museum.

Eucalyptus angusta Velenovsky.

Eucalyptus angusta Velenovsky, Die Flora der böhmischen Kreideformation, pt. 4, p. 3, pl. 3, figs. 2–12, 1885.
Berry, U.S. Geol. Survey Prof. Paper 84, p. 119, pl. 20, figs. 2–4, 1914.

This species was recently discussed by me for the eastern Gulf area in the paper cited.

It may well be doubted whether this and the preceding species are correctly referred to the genus *Eucalyptus*. Were it not for the havoc which would be wrought with the synonymy and the obscuring of their bearing on geographic distribution, I would refer these forms to the myrtaceous genus *Myrcia*, which is so abundant in the existing flora of tropical America and whose foliage is not distinguishable from the adult leaves of *Eucalyptus*. *Myrcia* is represented in the Eocene floras of the Mississippi embayment by several species, some of which are undoubtedly descended from these Upper Cretaceous species of so-called *Eucalyptus*.

Occurrence: Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga. Ripley formation (Cusseta sand member), near Buena Vista, Marion County, Ga.

Collection: U. S. National Museum.

Family COMBRETACEAE.

Genus CONOCARPITES Berry, n. gen.

Leaves of small or medium size, lanceolate to ovate-lanceolate, and more or less falcate in outline, of a coriaceous texture, and comparable in venation and all other features with those of the existing monotypic genus *Conocarpus* Linné of the strand flora of tropical Africa and America.

Conocarpites formosus Berry, n. sp.

Plate XXVIII, figure 9.

Leaves of medium size, about 7 centimeters in length by 2.5 centimeters in maximum width, which is halfway between the apex and the base. Outline ovate-lanceolate, slightly falcate, but the leaf is practically equilateral. Apex and base about equally acuminate. Petiole short and stout. Midrib stout, curved. Secondaries thin and for the most part immersed, five or six pairs, branching from the midrib at angles of more than 45°, curving upward, at length camptodrome. Tertiaries immersed. Texture coriaceous, the surface of the fossil form with the identical, somewhat granular appearance of the leaves in herbarium material of *Conocarpus erectus*.

This species, in its venation, texture, and outline, is very close to the larger leaves of the single recent species of *Conocarpus*.

The single recent species is widespread along low muddy or sandy tropical shores in Central and South America, and on the west coast of Africa (Guinea and Senegambia). It is said to occur in the Galapagos Islands on the Pacific coast of South America, and it extends northward from the West Indies to the Florida Keys and to Bermuda, where it is found on the sand dunes. Its distribution is effected almost entirely through the agency of ocean currents. Not only is it a member of the ecologically specialized mangrove associations, but it is equally at home on sandy strand and dunes.

The genus *Conocarpus* has been detected by the writer in the undescribed Eocene flora of the Wilcox group of the Mississippi embayment area, and a typical species has been described from the Jackson group of the Eocene deposits of Georgia.[1] Though it is unknown in European Tertiary deposits it is represented in that area by very similar leaves which are referred to the allied genus *Eugenia.*

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County, Ala. (collector, E. W. Berry).

Collection: U. S. National Museum.

Order UMBELLALES.

Family ARALIACEAE.

Genus ARALIA Linné.

Aralia cottondalensis Berry, n. sp.

Plate XXVI, figures 1-3.

Aralia wellingtoniana Ward, in Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894 (not Lesquereux).

Leaves of medium size, trilobate, ranging from 7 to 13 centimeters in length, by 6.5 to 11 centimeters in maximum width, from tip to tip of the lateral lobes. Tips acute. Base broadly cuneate or rounded. Lobes conical, pointed, directed upward; the median the larger. Sinuses narrow, rounded, reaching about halfway to the base. Margins entire below, above somewhat irregularly crenate, approaching serrate in some specimens. Primaries three in number, from a point at or very near the extreme base, the laterals diverging from the midrib at angles of about 25°, running to the tips of the lobes. Secondaries numerous, thin, approximately parallel, craspedodrome.

This species, which was confused by Ward with *Aralia wellingtoniana* Lesquereux, is common at the Cottondale locality, although most of the specimens are more or less fragmentary. It may be distinguished from this well-known species by the shorter, more conical lobes, the rounded instead of the conspicuously decurrent base, and the different character of the marginal teeth. It resembles somewhat *Aralia looziana* Saporta and Marion, a European lower Eocene species recorded by Ward in the Fort Union formation of the West.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Aralia eutawensis Berry.

Aralia eutawensis Berry, U. S. Geol. Survey Prof. Paper 84, p. 119, pl. 20, fig. 7, 1914.

This species was recently described by me from the eastern Gulf area in the paper cited, and the discussion need not be repeated here.

Occurrence: Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga.

Collection: U. S. National Museum.

Genus PANAX Linné.

Panax cretacea Heer.

Plate XXVI, figures 4, 5.

Panax cretacea Heer, Flora fossilis arctica, vol. 3, Abt. 2, p. 114, pl. 32, figs. 9, 9b, 9c, 9d, 10, 1874.
Hollick, The Cretaceous flora of southern New York and New England, p. 100, pl. 38, fig. 7, 1906.

Heer's original description, published in 1874, is as follows:

> P. fructibus bicarpellaribus, acheniis complanatis, rotundatis, subtilissime regulosis.

This little fruit was described by Heer from rather well preserved material collected in the Atane beds of western Greenland. A single specimen of a form that appears to be identical with the Greenland material was recently described by Hollick, from the Magothy formation of Gay Head, Marthas Vineyard. The species is also represented by a single specimen in the lower part of the Tuscaloosa formation. It is broadly obcordate in outline and is 5 millimeters in total height by 6.5 millimeters in width.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

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[1] Berry, E. W., U. S. Geol. Survey Prof. Paper 84, p. 147, pl. 29, figs. 4-7, 1914.

Family CORNACEAE.

Genus NYSSA Linné.

Nyssa snowiana Lesquereux.

Plate XXVI, figure 6.

Nyssa snowiana Lesquereux, The flora of the Dakota group, p. 126, pl. 52, fig. 11, 1892.

Leaves of relatively small size for this genus, broadly ovate in outline, abruptly contracted to a short acuminate tip, cuneate and finally slightly decurrent to the short, stout petiole. Length 5.5 centimeters. Greatest width, which is about halfway between the apex and the base, 3.3 centimeters. Petiole 6 millimeters long. Margins entire. Midrib rather stout, curved. Secondaries six to nine subopposite pairs branching from the midrib at angles of about 45° and sweeping upward in broad, gentle curves, camptodrome, as are their tertiary branches in the marginal part of the leaf.

This material from Alabama is clearly identical with that described by Lesquereux from the Dakota sandstone of Kansas, the type of which is in the collection of the University of Kansas (No. 935). These leaves in all of their characters are clearly referable to the Cornaceae and are associated with striated fruits which have been named *Nyssidium*. One other Cretaceous species has been described by Newberry from the Dakota sandstone. Throughout the Tertiary *Nyssa* is represented by a variety of species widely distributed and extending to Alaska on the one hand and Spitzbergen on the other. These occurrences are based for the most part upon characteristic fruits. There are a number of European species, some of which persist as late as the Pliocene, although the genus is not represented in the existing flora of Europe. In North America the genus has always been well represented, the Tertiary lignites of Vermont in particular containing an extraordinary variety of fruits of this genus. In existing floras *Nyssa* is confined to the eastern United States, with five species, and southern Asia with two species. A number of these species occur in small areas, and all are mesophytic types, the majority being confined to low swamps, and to estuary, river, and pond margins, mostly near the coast, the center of distribution of the American species being Georgia.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Genus CORNOPHYLLUM Newberry.

[U. S. Geol. Survey Mon. 26, p. 119, 1896.]

Cornophyllum vetustum Newberry.

Cornophyllum vetustum Newberry, The flora of the Amboy clays, p. 119, pl. 19, fig. 10, 1896.
Berry, New Jersey Geol. Survey Bull. 3, p. 196, 1911.

Leaves elliptical in outline, 7 to 8 centimeters in length by about 4 centimeters in maximum width, with an acute apex and base, the latter slightly decurrent and inequilateral. Margin entire, very slightly and inconspicuously undulate. Midrib slender and straight. Secondaries slender, about seven pairs, opposite or alternate, branching from the midrib at angles of about 45° and strongly curved upward, approximately parallel and camptodrome; they increase in length from the apex to the base, the lower ones sweeping upward in strong arches parallel with the margin and all drawn inward toward the apex.

With the exception of the delicate and somewhat flexuous character of the venation, these leaves are strictly comparable with those of *Cornus*, good species of which, very similar to this species, occur in the Dakota sandstone of the West, in Greenland, and in the Magothy formation of Maryland. Doubtless the Raritan species will eventually be referred to that genus, but meanwhile the present generic appellation is a sufficient index to its relationship.

This species is rather rare, both in New Jersey and Alabama and, as indicated above, serves to ally them with somewhat younger formations.

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County, Ala.

Collections: U. S. National Museum (type from New Jersey in New York Botanical Garden).

Cornophyllum obtusatum Berry, n. sp.

Plate XXVI, figures 7, 8.

Leaves of medium, or large size, elliptical or obovate in general outline, with a broadly rounded apex and a cuneate or slightly decurrent base. Length ranges from 5.5 to 10 centimeters. Maximum width ranges from 3.3 to 5 centimeters, halfway between the apex and the base. Margin entire, slightly repand in places. Petiole short and stout. Midrib stout and flexuous. Secondaries thin, five or six pairs branching from the midrib at angles of

45° or less, usually less, and sweeping upward in long, more or less flexuous curves, approximately parallel with the lateral margins, eventually camptodrome, distinctly of the type usually associated with *Cornus*, *Rhamnus*, or *Berchemia*.

This new species is clearly allied with *Cornus*, the principal difference being that of outline and irregularity of venation. It differs from the only other known species of *Cornophyllum*, that from the Raritan formation of New Jersey, in its obtuse apex. Outside the lower part of the Tuscaloosa formation it is sparingly represented in the Black Creek formation of North Carolina.

Occurrence: Tuscaloosa formation, Cottondale, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Order ERICALES?

Family ERICACEAE?

Genus ANDROMEDA Linné.

Andromeda novaecaesareae Hollick.

Plate XXX, figures 1, 2.

Andromeda novaecaesareae Hollick, in Newberry, The flora of the Amboy clays, p. 121, pl. 42, figs. 9–12, 28–31, 1896.

Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.

Berry, Torrey Bot. Club Bull., vol. 33, p. 181, 1906, idem, vol. 34, p. 204, 1907; idem, vol. 43, p. 301; 1916; New Jersey Geol. Survey Bull. 3, p. 204, pl. 25; fig. 6, 1911.

Leaves small, thick, and entire, with stout petioles and midribs and obscure secondary venation which is immersed in the thick lamina. Length 2.5 to 5 centimeters. Width varying from 0.9 centimeter to 1.3 centimeters. Venation, where visible, showing numerous parallel, camptodrome, relatively long and thin secondaries which branch from the midrib at acute angles. Though the majority of these leaves are equally acuminate at both ends there is considerable variation in this respect, and a well-marked tendency is shown in many specimens which are relatively broader, especially in the upper half, toward an obtusely rounded apex, the termination of the midrib showing as a small mucronate point. The base in these forms gradually narrows to the stout petiole. The variations in outline of this species are well shown in the figures reproduced in Newberry's monograph. The specimens collected from the South Atlantic Coastal Plain seem to have an obtusely rounded apex more commonly than those from New Jersey.

In the Raritan formation this species is only known with certainty from the uppermost beds at South Amboy, N. J. It becomes more abundant in the overlying Magothy formation, occurring from New Jersey to Maryland in beds of this age. Farther south it is found as one of the typical fossils of the Black Creek formation in North Carolina, being a prominent but never abundant element in the dark lignitic laminated clays of the upper beds associated with *Araucaria*, *Cunninghamites*, *Pistia*, and other forms and a marine fauna.

It occurs in the Middendorf arkose member of the Black Creek formation of South Carolina and is also present in Georgia. It has not been observed to be common in the Tuscaloosa formation, being only known from beds near the base. However, the abundance of this species at somewhat higher horizons in Georgia and Tennessee would indicate that its rarity in the Tuscaloosa deposits may be more apparent than real.

It may well be questioned whether this and the following species of *Andromeda* should be referred to the Ericales. Certainly the present form has numerous points of contact with the leaves of *Eugenia*, which has been positively recognized in the lower Eocene floras of this general region and doubtfully from both the Tuscaloosa and Ripley formations.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen (Ward's determination), Fayette County; big gully on the Snow place, Tuscaloosa County, Ala. Ripley formation (Cusseta sand member), near Buena Vista, Marion County, Ga. Eutaw formation (Coffee sand member), Coffee Bluff, Hardin County, Tenn.

Collections: U. S. National Museum.

Andromeda grandifolia Berry.

Plate XXVII, figure 7.

Andromeda grandifolia Berry, Torrey, Bot. Club Bull., vol. 34, p. 204, pl. 15, fig. 3, 1907; New Jersey Geol. Survey Bull. 3, p. 205, pl. 26, figs. 1, 2, 1911.

Andromeda latifolia Newberry, The flora of the Amboy clays, p. 120, pl. 33, figs. 6-8, 10 (not fig. 9); pl. 34, figs. 6-11, pl. 34, fig. 10, 1896 (not Wright).

Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.

Hollick, New York Bot. Garden Bull., vol. 3, p. 416, pl. 79, fig. 3, 1904; The Cretaceous flora of southern New York and New England, p. 100, pl. 39, fig. 1, 1906.

Leaves thick and coriaceous, varying considerably in size and shape. From 4 to 20 centimeters in length, by 1.5 to 7 centimeters in width. Ovate-lanceolate in outline with an entire, usually somewhat undulate or unsymmetric margin. Apex obtusely pointed or in some specimens rounded. Base somewhat wedge-shaped. Midrib and petiole very stout. Secondaries relatively few, 6 to 8 pairs, stout and flexuous, branching from the midrib at acute angles and sweeping upward in long curves, eventually inosculating to complete the strictly camptodrome venation.

This species occurs from the lower part of the Raritan formation of New Jersey to the top of the eastern leaf-bearing Cretaceous. It is a common fossil in the Magothy formation, the Black Creek formation of North Carolina, and the Tuscaloosa formation of Alabama. It is larger, relatively broader, and less regular than *Andromeda parlatorii* Heer.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, upper ravine on the Snow place, Fayette County; university grounds, Tuscaloosa, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Andromeda parlatorii Heer.

Andromeda parlatorii Heer, Phyllites crétacées du Nebraska, p. 18, pl. 1, fig. 5, 1866; Flora fossilis arctica, vol. 3, Abt. 2, p. 112, pl. 32, figs. 1, 2, 1874; idem, vol. 6, p. 79, pl. 21, figs. 1b, 11; pl. 42, fig. 4c, 1882.

Lesquereux, The Cretaceous flora, p. 88, pl. 23, figs. 6, 7; pl. 28, fig. 15, 1874; The flora of the Dakota group, p. 115, pl. 19, fig. 1; pl. 42, fig. 6, 1892.

Newberry, The flora of the Amboy clays, p. 120, pl. 31, figs. 1-7; pl. 33, figs. 1, 2, 4, 5, 1896.

Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.

Hollick, New York Acad. Sci. Ann., vol. 11, p. 420, pl. 37, figs. 1-4, 1898; The Cretaceous flora of southern New York and New England, p. 101, pl. 39, figs. 2-5, 1906.

Berry, New York Bot. Garden Bull., vol. 3, p. 97, pl. 1, figs. 1-4, 1903; Torrey Bot. Club Bull., vol. 31, p. 79, pl. 1, figs. 1, 2, 1904; idem, vol. 33, p. 181, 1906; idem, vol. 34, p. 203, pl. 15, fig. 2, 1907; Johns Hopkins Univ. Circ., new ser., No. 7, p. 81, 1907; New Jersey Geol. Survey Bull. 3, p. 206, pl. 27, figs. 1-4, 1911.

Prunus? parlatorii (Heer) Lesquereux, Am. Jour. Sci., 4th ser., vol. 36, p. 102, 1868.

Leucothoe parlatorii (Heer) Schimper, Paléontologie végétale, vol. 3, p. 11, 1874.

Leaves ovate-lanceolate in outline, with a long and gradually narrowed apex, and a broad, somewhat rounded but finally cuneate or slightly decurrent base. Petiole and midrib stout. Length about 10 to 12 centimeters. Maximum width about 3 centimeters in the lower half of the leaf. Secondaries numerous, rather thin, subparallel, branching from the midrib at acute angles, long and ascending, at length camptodrome. Tertiaries mostly straight, transverse. There is considerable variation in the size of these leaves and in the angles which the secondaries form with the midrib, and consequently in their length and degree of curvature. Some of the specimens approach closely in appearance to the small leaves of *Andromeda grandifolia* Berry, which are more slender and apically attenuated than the normal-sized leaves of that species.

This species was first described by Prof. Heer in one of the earliest published accounts of the Dakota sandstone flora, and it has since been found to have a wide geographic range. It is one of the commonest fossils in the Dakota sandstone, having been recorded from Minnesota, Kansas, and Nebraska. In eastern North America it is recorded from the Atane beds of Greenland, the Magothy formation on Marthas Vineyard, the Raritan formation of New Jersey, the Magothy formation of New Jersey, Delaware, and Maryland, the Black Creek formation of North Carolina, and the Middendorf arkose member of the Black Creek formation of South Carolina. In Alabama it is common in the Tuscaloosa formation and extends into the lower beds of the Eutaw formation in Hale County.

The genus *Andromeda* of Linné has been much segregated by the subsequent taxonomists, and this is reflected in Schimper's proposal to refer this species to the genus *Leucothoe*. However, the more comprehensive name has obvious advantages for the paleobotanists in dealing with material where it is impossible to discriminate between the ericaceous genera with any degree of accuracy.

Occurrence: Tuscaloosa formation, Glen Allen and Shirleys Mill, Fayette County; university grounds, upper ravine and big gully on the Snow place, Cottondale, and gully at Tuscaloosa County, Ala. Eutaw formation (basal beds), 2 miles south of Havana, Hale County, Ala.

Collection: U. S. National Museum.

Andromeda wardiana Lesquereux.

Plate XXVII, figure 6.

Andromeda wardiana Lesquereux, The flora of the Dakota group, p. 119, pl. 64, fig. 17, 1892.
Berry, U. S. Geol. Survey Prof. Paper 84, p. 120, pl. 24, fig. 3, 1914.

Leaf narrowly elliptical in outline, with an entire margin. Apex and base about equally narrowed, the former bluntly rounded. Size somewhat variable. Length 4.7 to 6.5 centimeters. Maximum width 2 to 2.5 centimeters about halfway between the apex and the base. Midrib thin but prominent. Secondaries thin, five or six subparallel pairs diverging from the midrib at angles of about 40°, ascending, eventually camptodrome.

The type of this species came from the Dakota sandstone of Ellsworth County, Kans., and constituted the only known occurrence until a few years ago, when I collected it at the base of the Eutaw formation in western Georgia. The present occurrences are from the basal part of the Tuscaloosa formation near Shirleys Mill, Ala., and from a horizon in northeastern Mississippi which is nearly equivalent to the one in Georgia.

Occurrence: Tuscaloosa formation, cut on Southern Railway 1⅝ miles east of Iuka, Tishomingo County, Miss. (collected by L. W. Stephenson); Shirleys Mill, Fayette County, Ala. (collected by E. W. Berry). Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga.; (Coffee sand member), Coffee Bluff, Hardin County, Tenn.

Collection: U. S. National Museum.

Andromeda cretacea Lesquereux (?).

Andromeda cretacea Lesquereux, The flora of the Dakota group, p. 117, pl. 17, figs, 17, 18; pl. 24, fig. 5, 1892.
Berry, U. S. Geol. Survey Prof. Paper 84, p. 120, pl. 24, fig. 2, 1914.

The probable occurrence of this species in the eastern Gulf area was recently discussed by me in the paper cited above and need not be repeated here.

Occurrence: Eutaw formation (basal beds), McBrides Ford, Chattahoochee County, Ga.

Collection: U. S. National Museum.

Genus DERMATOPHYLLITES Goeppert.

Dermatophyllites acutus Heer.

Plate XXVII, figure 8.

Dermatophyllites acutus Heer, Flora fossilis arctica, vol. 6, pt. 2, p. 80, pl. 42, fig. 7, 1882.

Heer's description of this species, published in 1882, is as follows:

> D. foliis minutis, coriaceis, anguste lanceolatis, apice acute acuminatis, basim versus attenuatis, integerrimis, nervo medio valido, nervis secundariis nullis.

Heer referred this tiny leaf, along with another species from the same horizon, to the genus *Dermatophyllites*, established by Goeppert for several Tertiary species of Ericaceae. Heer's species certainly occurs in the Tuscaloosa formation, showing that it had a very extensive latitudinal range. The indicated botanic affinity is entirely problematic, so that the name stands as given by the original describer.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Genus KALMIA Linné (?).

Kalmia brittoniana Hollick.

Kalmia brittoniana Hollick, New York Acad. Sci. Trans., vol. 12, p. 34, pl. 2, figs. 6-8, 1892; The Cretaceous flora of southern New York and New England, p. 100, pl. 39, figs. 8, 9, 1906.
Berry, Torrey Bot. Club Bull., vol. 34, p. 204, 1907.

Leaves of small size, petiolate, oblong-elliptical in general outline, with a rounded apex and a cuneate base. Length about 2.75 centimeters. Maximum width 6 or 7 millimeters in the middle part. Midrib prominent. Secondaries obsolete. Texture coriaceous.

This small-leafed species was described by Hollick from the Raritan formation on Staten

Island and subsequently recorded by me from the Black Creek formation of North Carolina. I do not believe that there is any foundation for its reference to the genus *Kalmia* or even to the Ericaceae. It probably represents some Upper Cretaceous species of Proteaceae or Myrtaceae.

Remains identical with the type are present in the Tuscaloosa formation.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Order PRIMULALES.

Family MYRSINACEAE.

Genus MYRSINE Linné.

Myrsine gaudini (Lesquereux) Berry.

Myrsinites? gaudini Lesquereux, The flora of the Dakota group, p. 115, pl. 52, fig. 4, 1892.

Myrsine gaudini (Lesquereux) Berry, Torrey Bot. Club Bull., vol. 36, p. 262, 1909; New Jersey Geol. Survey Bull. 3, p. 210, pl. 24, figs. 3, 4, 1911.

Myrsine elongata Newberry, MSS. Hollick, Torrey Bot. Club Bull., vol. 21, p. 54, pl. 177, fig. 2, 1894; New York Acad. Sci. Ann., vol. 11, p. 420, pl. 38, figs. 3, 4b, c, 1898; The Cretaceous flora of southern New York and New England, p. 102, pl. 8, fig. 1b; pl. 39, figs. 13, 14, 1906.
Newberry, The flora of the Amboy clays, p. 122, pl. 22, figs. 1-3, 1896.

Leaves oblanceolate or elongate-obovate in outline, 5.5 to 7 centimeters in length by 1.9 to 2.5 centimeters in greatest width. Margins entire. Apex obtusely rounded. Base somewhat elongated, narrowly cuneate. Petiole present, stout. Midrib stout below, diminishing in caliber in a short distance. Secondaries numerous, 8 to 10 pairs, alternate, branching from the midrib at angles of 40° to 45°, camptodrome. When tertiary venation is distinctly preserved, the venation is more typical of the genus than when only the secondaries are partly visible. This species is well distributed in the Raritan formation of New Jersey and has been recorded also from Long Island and Staten Island. The identification of *Myrsinites? gaudini* Lesquereux, with the eastern forms with which it is obviously identical, extends the range eastward from Kansas to Long Island. It may be readily distinguished from the other species of *Myrsine* by its relatively narrow, elongated form. It is present in the Black Creek formation of North Carolina and in the Middendorf arkose member of that formation in South Carolina. It is not abundant in the Alabama Cretaceous and is only present in the basal beds of the Tuscaloosa formation in western Alabama.

Occurrence: Tuscaloosa formation, roadside southwest of Northport, Cottondale, Tuscaloosa County; Glen Allen, Fayette County, Ala.

Collection: U. S. National Museum.

Myrsine borealis Heer.

Myrsine borealis Heer, Flora fossilis arctica, vol. 3, Abt. 2, p. 113, pl. 32, fig. 23, 1874; idem, vol. 6, Abt. 2, p. 81, pl. 24, figs. 7b, 8; pl. 27, fig. 1b; pl. 44, fig. 5a; pl. 46, figs. 19, 20, 1882.
White, Am. Jour. Sci., 3d ser., vol. 39, p. 98, pl. 2, fig. 5, 1890.
Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.
Newberry, The flora of the Amboy clays, p. 122, pl. 24, figs. 4-6, 1896.
Hollick, Geol. Soc. America Bull., vol. 7, p. 13, 1895; The Cretaceous flora of southern New York and New England, p. 102, pl. 39, figs. 10, 11, 1906.
Berry, New Jersey Geol. Survey Bull. 3, p. 208, pl. 24, fig. 2, 1911.

Diospyros rotundifolia Lesquereux. Hollick, Torrey Bot. Club Bull., vol. 21, p. 53, pl. 179, fig. 2, 1894.

Heer's original description of this species, published in 1874, is as follows:

M. foliis ovatis (?), integerrimis, nervis secundariis numerosis, approximatis, ramosis, camptodromis.

Leaves ovate-elliptical in outline, obtusely rounded above and slightly cuneate below, 2.5 to 5 centimeters in length by 1.2 to 3 centimeters in maximum width, with a stout petiole about 1 centimeter in length. Margins entire. Texture coriaceous, more or less obscuring the venation. Midrib stout. Secondaries rather stout, five to eight alternate pairs, parallel, branching from the midrib at acute angles, camptodrome. Tertiaries fine, forming an inosculating series of elongated meshes, more or less parallel with the secondaries. In specimens in which the tertiary venation is visible the appearance is very different from that shown in Newberry's figures, where only the secondaries are seen. Newberry's specimens may be compared with the similarly preserved leaves from Greenland, figured by Heer.[1]

This species was described originally from the Atane beds of Greenland by Heer and was subsequently collected in considerable abundance from the Raritan formation in New Jersey. It has also been recorded from Marthas Vineyard and Long Island, and from the Black Creek formation in North Carolina. In Alabama, so far as known, it is confined to the lower part of the Tuscaloosa formation of Fayette County, where it is not especially common.

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[1] Heer, Oswald, Flora fossilis arctica, vol. 6, pl. 24, fig. 8; pl. 44, fig. 5a, 1882

Occurrence: Tuscaloosa formation, Shirleys Mill, Glen Allen, Fayette County; big gully on the Snow place, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Order EBENALES.

Family EBENACEAE.

Genus DIOSPYROS Linné.

Diospyros primaeva Heer.

Plate XXX, figure 3.

Diospyros primaeva Heer, Phyllites crétacées du Nebraska, p. 19, pl. 1, figs. 6, 7, 1866; Flora fossilis arctica, vol. 6, Abt. 2, p. 80, pl. 18, fig. 11, 1882; idem, vol. 7, p. 31, pl. 51, figs. 5a, b, c, 1883.

Englehardt, Naturwiss. Gesell. Isis in Dresden Abh. 7, Jahrg. 1891, p. 98, 1892.

Lesquereux, The flora of the Dakota group, p. 109, pl. 20, figs. 1-3, 1892.

Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.

Newberry, The flora of the Amboy clays, p. 124, pl. 30, figs. 1-5, 1896.

Knowlton U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 317, pl. 39, fig. 3, 1901.

Berry, Torrey Bot. Club Bull., vol 32, p. 46, pl. 2, 1905; idem, vol. 34, p. 204, 1907; idem, vol. 38, p. 417, 1911; New Jersey Geol. Survey Bull. 3, p. 211, pl. 29, fig. 1, 1911.

Hollick, The Cretaceous flora of southern New York and New England, p. 103, pl. 42, figs. 2, 11, 1906.

Leaves oblong-ovate in outline, variable according to age, ranging from 3 to 15 centimeters in length, by 1.3 to 5 centimeters in greatest width, which is in the middle part of the leaf. Apex acute or obtuse. Base cuneate. Margins entire. Petiole rather long and very stout. Midrib also stout. Secondaries branching from the midrib, generally at acute angles, subopposite or alternate, parallel camptodrome. Tertiaries forming polygonal areoles whose relative prominence is one of the features of this species.

This species, which is quite suggestive of the modern *Diospyros virginiana* Linné, was described by Heer from the Dakota sandstone of Nebraska nearly half a century ago. It has proved to be a form of very wide range, having been identified at both the Atane and Patoot horizons in Greenland and from the Cenomanian of Niederschoena in Saxony; from various localities within the Dakota sandstone, including its southern extension, the Woodbine sand of Texas; and with the exception of the fragments from Marthas Vineyard and Long Island, which are of questionable identity, it is common in the Raritan and Magothy formations, or homotaxial equivalents, from New Jersey to Alabama.

Its most marked character is the prominence of its tertiary areolation. It is common at various localities in the lower part of the Tuscaloosa formation of western Alabama and continues upward into those beds in Hale County which have been placed in the basal portion of the Eutaw formation and into the Coffee sand member in Tennessee.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, Fayette County; Cottondale; gully at Tuscaloosa, Tuscaloosa County, Ala. Eutaw formation (basal beds), 2 miles south of Havana, Hale County, Ala.; (Coffee sand member), Coffee Bluff, Hardin County, Tenn.

Collection: U. S. National Museum.

Diospyros amboyensis Berry.

Plate XXVII, figure 5.

Phyllites ellipticus Newberry, The flora of the Amboy clays, p. 130, pl. 24, fig. 9, 1896.

Diospyros amboyensis Berry, Torrey Bot. Club Bull., vol. 36, p. 262, 1909; New Jersey Geol. Survey Bull. 3, p. 212, pl. 29, fig. 5, 1911.

Leaves elliptical in outline, large, 8 to 9 centimeters long by 4.6 to 5 centimeters wide; margin more or less undulate; apex slightly narrowed, rounded, almost retuse; base broadly rounded, thus differing from the wedge-shaped base of *Diospyros primaeva* Heer; midrib strong, although not so strong as in *D. primaeva;* secondaries thin, numerous, 8 to 10 pairs, regular, leaving the midrib at an angle of about 45°, camptodrome; tertiary venation of large polygonal meshes, finer in caliber than in *D. primaeva.*

The type was a single specimen from the Raritan formation at Woodbridge, N. J. Similar remains are sparingly represented in the collections from the basal beds of the Tuscaloosa formation. One of the leaves which Heer identifies from Atane schists of Greenland as *Populus hyperborea*,[1] though the apex is partly destroyed and the tertiaries are not shown, is very similar to the species under discussion. This similarity does not extend, however, to the other leaves identified as this species.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Diospyros rotundifolia Lesquereux.

Plate XXVII, figure 4; Plate XXX, figures 4, 5.

Diospyros rotundifolia Lesquereux, The Cretaceous flora, p. 89, pl. 30, fig. 1, 1874; The flora of the Dakota group, p. 112, pl. 17, figs. 8–11, 1892.

Berry, New Jersey Geol. Survey Ann. Rept. for 1905, p. 139, 1906; Torrey Bot. Club Bull., vol. 33, p. 181, 1906.

Leaves entire, variable in size, 4 to 10 centimeters in length, by 2 to 7 centimeters in maximum width, which is in the middle part. Outline broadly oval or elliptical. Apex broadly rounded. Base similarly rounded or somewhat narrowed and pointed. Petiole and midrib stout. Secondaries 6 or 7 pairs, branching from the midrib at angles of 50° to 60°, arched, camptodrome. Texture subcoriaceous. Venation less prominent than in *Diospyros primaeva* Heer.

This species is a characteristic element in the post-Raritan flora of the Atlantic Coastal Plain, although at times it is liable to be confused with *Myrsine borealis* Heer, or with some of the smaller, more orbicular, entire leaves of *Populus*. The venation is markedly different, however.

Diospyros rotundifolia was described originallyfrom the Dakota sandstone of Kansas, and it is common in the Magothy formation in New Jersey, Delaware, and Maryland. In South Carolina it has only been found at a single locality in the Middendorf arkose member of the Black Creek formation. It is not rare in the lower part of the Tuscaloosa formation of western Alabama.

Occurrence: Tuscaloosa formation, Shirleys Mill, Glen Allen, Fayette County, Ala.

Collections: U. S. National Museum.

Family SAPOTACEAE.

Genus SAPOTACITES Ettingshausen.

Sapotacites ettingshauseni Berry, n. sp.

Plate XXIX, figure 7.

Leaves inversely triangular in general outline with a broad, slightly emarginate apex, rounded at the outer angles, and a cuneate base, about 4 centimeters in length by 4 to 5 centimeters in maximum width, which is at or above the middle. The margins are entire, straight below and full above, the apical margin slightly undulate and somewhat emarginate at apex of the midrib. Texture somewhat coriaceous. Petiole short or wanting. Midrib stout. Secondaries thin, three or four opposite or subopposite pairs. They branch from the midrib at angles of about 45° and pursue a slightly curved course almost to the margin, where they curve upward to join a lateral branch of the secondary next above. Tertiaries fine, arched along the margins; internally they are mostly transverse, forming somewhat irregular rectangular areoles.

This species is named in honor of the late Baron von Ettingshausen, who founded this genus in 1853 for those fossil leaves which are referable to the family Sapotaceae but which it is impossible to assign definitely to any of the existing genera. Perhaps a score of such species have been described. These range in age from the mid-Cretaceous of Europe and America through the Tertiary. The present species somewhat resembles certain genera of the Leguminosae, for example *Colutea* and *Amicia*. It is also much like the East Indian species *Mimusops obovata*.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Sapotacites shirleyensis Berry, n. sp.

Plate XXVIII, figure 11; Plate XXIX, figures 4–6.

Leaves rather small in size, elliptical in general outline, with a deeply emarginate apex and slightly decurrent base. Length 3.3 centimeters along the midrib, 4 centimeters from a line connecting the tips of lateral wings to the base, about 3 centimeters or slightly less in maximum width, which is about midway between the apex and the base. Margin entire, full and rounded, the apical lateral angles directed upward and rounded. Apical sinus extending one-fifth to one-sixth of the distance to the base, its margins nearly straight, forming an angle of about 65°. Petiole short or wanting. Midrib stout. Secondaries thin, two or three alternate pairs, branching from the midrib at angles of about 45° and curving upward parallel with the lateral margin, eventually camptodrome. Tertiaries thin, arched along the margins and forming rectangular meshes internally. These are more regular and smaller than in *Sapotacites ettingshauseni.*

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[1] Heer, Oswald, Flora fossilis arctica, vol. 3, Abt. 2, pl. 29, figs. 6, 18, 1874.

The present species, though different in general appearance, is close to *Sapotacites ettingshauseni,* differing in the elliptical instead of triangular outline, the full margins, rounded base, deep apical sinus, and alternate curved secondaries, features which would be largely duplicated if the tips in that species were directed upward instead of outward and brought toward each other in the line of the midrib. The present species resembles somewhat various described fossil species which have been referred to the genus *Colutea,* more especially *Colutea protogaea* Heer of the Greenland Cretaceous. However, the two species are believed to be perfectly distinct. I consider it undoubtedly ancestral to a common form of the lower Eocene of the Mississippi embayment area, which I have described in manuscript as a species of *Bumelia.*

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Sapotacites formosus Berry, n. sp.

Plate XXX, figure 6.

Leaves of medium size, broadly elliptical in general outline, with a broadly rounded or slightly retuse apex, and a broad more or less decurrent base. Length about 4.75 centimeters. Maximum width, in the middle part of the leaf, about 3.25 centimeters. Margins entire, evenly rounded. Leaf substance thick and coriaceous. Petiole short and stout. Midrib very stout, especially proximad, somewhat flexuous. Secondaries stout, five or six alternate, irregularly spaced pairs; they diverge from the midrib at wide angles, between 60° and 65°, and are camptodrome in the marginal region. This species, which is clearly allied to various modern species of Sapotaceae, especially of the genera *Bumelia* and *Mimusops,* is much like the forms from the Dakota sandstone, *Sapotacites haydenii* Heer [1] and *Phyllites obcordatus* Heer.[2] The latter is described by Lesquereux as *Bumelia marcouana;*[3] it is most like the present species but is broader toward the apex and more narrowed toward the base, with thinner venation and texture and more retuse apex. *Sapotacites formosus* is very similar to the Raritan species, *Populus orbicularis* (Newberry) Berry,[4] and is also much like several lower Eocene species collected in the embayment area, which will be described by the writer as species of *Bumelia* and *Mimusops* in a subsequent publication. Some of these are unquestionably descended from the *Sapotacites formosus.*

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Order GENTIANALES.

Family ASCLEPIADACEAE.

Genus ACERATES Nilsson.

Acerates amboyensis Berry.

Acerates amboyensis Berry, Torrey Bot. Club Bull., vol. 36, p. 263, 1909; New Jersey Geol. Survey Bull. 3, p. 214, 1911.

Acerates sp. Hollick, in Newberry, The flora of the Amboy clays, p. 124, pl. 32, fig. 17; pl. 41, figs. 4, 5, 1896.

Leaves narrow and elongated, somewhat falcate, lanceolate or linear-lanceolate, 5 to 7.5 centimeters in length by 5 to 8 millimeters in maximum width, gradually narrowed above and cuneate below. Margins entire, somewhat undulate. Petiole apparently wanting. Texture thick. Secondaries numerous, rather angular, branching from the midrib at acute angles, camptodrome.

This well-marked species was described by Newberry from the upper part of the Raritan formation of New Jersey, and I have detected it in the Black Creek formation of North Carolina, and several species of *Acerates* have been described by Prof. Heer from the Cretaceous deposits of western Greenland.

Though not common, unmistakable remains of this species, clearly allied to the modern representatives of this genus, are present in western Alabama.

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[1] Newberry, J. S., The later extinct floras of North America: U. S. Geol. Survey Mon. 35, p. 126, pl. 5, fig. 1, 1898.

[2] Idem, p. 136, pl. 5, fig. 2.

[3] Lesquereux, Leo, The Cretaceous flora, p. 90, pl. 28, fig. 2, 1874.

[4] Berry, E. W., New Jersey Geol. Survey Bull. 3, p. 112, pl. 11, figs. 5, 6, 1911.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County; Sanders Ferry Bluff, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

Order POLEMONIALES.

Family BORRAGINACEAE.

Genus CORDIA Linné.

Cordia apiculata (Hollick) Berry, n. comb.

Plate XXX, figures 7, 8.

Populus apiculata Hollick, New York Acad. Sci. Trans., vol. 12, p. 4, pl. 3, fig. 2, 1892; The Cretaceous flora of southern New York and New England, p. 49, pl. 7, figs. 28, 29, 1906 (?).
Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.
Newberry, The flora of the Amboy clays, p. 65, pl. 15, figs. 3, 4, 1896.
Berry, Torrey Bot. Club Bull., vol. 33, p. 172, 1906; New Jersey Geol. Survey Bull. 3, p. 111, pl. 11, fig. 4, 1911.

Leaves variable in size and shape, ovate to orbicular in general outline, 5 to 10 centimeters in length by 3 to 7 centimeters in maximum width, which is at or below the middle. Apex usually somewhat abruptly produced into an acuminate tip. Base cuneate and slightly decurrent to rounded or almost truncate. Margins entire, in some specimens slightly repand. Petiole of medium length, stout. Midrib rather stout, commonly flexuous. Secondaries, 5 or 6 pairs, subopposite below, alternate above, slender, branching from the midrib at angles of 45° to 50° and arching upward, camptodrome. Tertiaries camptodrome in the marginal region, percurrent internally.

Newberry, the original describer of this species in manuscript, compared it with *Populus hyperborea* Heer and *P. berggreni* Heer but seemed doubtful of its real relation to *Populus*. This doubt seems to be well founded, for though these leaves are not unlike those usually referred to the genus *Populus*, this assumed relationship has by no means been proved for a number of the Upper Cretaceous forms so identified. Though it is not impossible that species of *Populus* may have flourished in the Gulf region during Tuscaloosa time, the association of a number of forms whose descendants are tropical led to an extended search among existing tropical American forms with the result that the present species is referred to the genus *Cordia*, which has more than 200 existing species of the Tropics, and warmer extratropical regions of both hemispheres, the majority being American and several reaching the Florida Keys, the Bahamas, and the valley of the Rio Grande. The fossil species in all its characters suggests most strongly the existing *Cordia sebestena* Linné which ranges from the Bahamas and Florida Keys to New Guinea in sandy soil not far from the coast. It also suggests *Cordia tremula* Grisebach of the West Indies, and there is a general generic likeness to other existing species of this genus. Leaves of the *Cordia* are variable and tend to have more or less toothed margins, as in some individuals of *Cordia sebestena*, but they are in general entire or slightly repand and like the fossil somewhat variable. *Cordia* is certainly represented in the lower Eocene flora of the Gulf region by forms that may be descendants of this Upper Cretaceous species. The present form has also been recorded from Staten Island and Long Island, from the Magothy formation of Delaware, and it is not rare in the lower beds of the Tuscaloosa formation.

Occurrence: Tuscaloosa formation, Glen Allen and Shirleys Mill, Fayette County; Cottondale, Tuscaloosa County, Ala.

Collections: U. S. National Museum; New York Botanical Garden.

POSITION UNCERTAIN.

Genus TRICALYCITES Hollick.

[Torrey Bot. Club Bull., vol. 21, p. 63, pl. 180, fig. 8, 1894.]

Tricalycites papyraceus Hollick.

Plate XXVIII, figures 1-5.

Tricalycites papyraceus Hollick, Torrey Bot. Club Bull., vol. 21, p. 63, pl. 180, fig. 8, 1894; New York Acad. Sci. Ann., vol. 11, p. 61, pl. 3, fig. 6, 1898; idem, p. 423, pl. 37, figs. 1, 2; New York Bot. Garden Bull., vol. 2, p. 405, pl. 41, fig. 3, 1902; The Cretaceous flora of southern New York and New England, p. 109, pl. 5, figs. 8-12, 1906; New York State Mus. Fifty-fifth Ann. Rept., p. r51, 1903.
Smith, On the geology of the Coastal Plain of Alabama, p. 348, 1894.
Newberry, The flora of the Amboy clays, p. 132, pl. 46, figs. 30-38, 1896.
Berry, Torrey Bot. Club Bull., vol. 31, p. 81, pl. 1, fig. 4, 1904; New Jersey Geol. Survey Bull. 3, p. 221, 1911.

Well-defined organisms, apparently dicotyledonous in their affinities and involucral or fructicose in their nature. They consist of a central nucleus, which is generally of small size, 1 to 3 millimeters in diameter, borne at the apex of a stout peduncle or stalk, 2 to 5 millimeters in length. To this nucleus usually three membranous wings are connate. These wings usually diverge from each other at angles of about 45°, although in some specimens they are almost parallel in their orientation; they are broadly linear, obovate or ovate in outline, with broadly rounded, almost truncate tips, and narrowed somewhat toward the base, the lateral wings being usually somewhat asymmetric and in typical material somewhat shorter and broader than the median wing; they are marked by fine, approximately parallel longitudinal veins, converging toward the base, which fork and anastomose, ultimately ending in the margins. In size they range from 0.5 centimeter to 2.5 centimeters in length by 2 to 10 millimeters in width. Both Hollick and Newberry call attention to the somewhat greater length of the middle wing, which is, however, far from being a constant character, for some specimens fail to show it, all of the wings being of approximately similar size, or the central wing may even be much smaller, as it is in some of the Alabama material figured, where along with the normal forms there occur others with all the wings directed upward and the central one only about half the size of the laterals. Most of the Alabama forms, however, are normal, as described above.

The botanic relation of these curious objects remains unknown, although they are probably comparable to the bracts so largely developed in some of the Juglandaceae, as, for example, in *Engelhardtia* and *Oreomunnea*, or to certain of the winged fruits to be found among the modern Sapindaceae. The writer has compared the fossils with a large amount of recent material in the New York Botanical Garden and the United States National Herbarium and feels some confidence in the belief that they may represent fruits of some Cretaceous member of the family Dipterocarpaceae. Superficially, the venation appears to consist of slightly diverging, approximately parallel, longitudinal striations. The Alabama material, however, shows clearly that these veins fork and anastomose, as shown in the figure reproduced from a photograph, which has been carefully verified from a large number of specimens, thus allying these fossils with such a modern genus as *Vatica*. Exact correspondence between these remote ancestral forms and any of the modern genera, which are all confined to the Eastern Hemisphere, is hardly to be expected.

In the abundant remains from Tottenville, Staten Island; Gay Head and Nashaquitsa, Marthas Vineyard; and Glen Cove, Long Island, Hollick has described another species, *Tricalycites major*,[1] based on forms which are usually two-winged and which have a larger nucleus, the wings reaching a length of 4 centimeters and a width of 1.3 centimeters. The same author has described similar but smaller remains from Marthas Vineyard as *Calycites obovatus*,[2] and still smaller remains from Montauk Point, Long Island, as *Calycites alatus*.[3] Though perhaps from the standpoint of the paleobotanist these segregations are permissible or even desirable, it may be doubted if they express real specific distinctions and not merely individual variations. There is certainly a suggestion in the forms from the Tuscaloosa formation of Alabama, which occur with the normal *Tricalycites papyraceus*, that the central wing may be more or less abortive or completely so, thus giving some terms of the series leading to *Tricalycites major* or to the almost identical smaller forms which are referred to *Calycites obovatus* and *C. alatus*.

Tricalycites papyraceus is abundant in the middle part of the Raritan formation at Woodbridge, N. J., and also occurs in the upper part of the Raritan formation at South Amboy, N. J. It occurs sparingly in the Magothy formation at Cliffwood Bluff, N. J., and is abundant in the insular Cretaceous floras along the southern coast of New England and is very common in the lower part of the Tuscaloosa formation in the Alabama area. It is also common in the Woodbine sand at Arthurs Bluff, Lamar County, Tex.

Occurrence: Tuscaloosa formation, Shirleys Mill and Glen Allen, Fayette County; big gully on the Snow place, Tuscaloosa County, Ala.

Collections: U. S. National Museum.

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[1] Hollick, Arthur, The Cretaceous flora of southern New York and New England: U. S. Geol. Survey Mon. 50, p. 108, pl. 8, figs. 13-22, 1907.

[2] Idem, p. 109, pl. 5, fig. 23.

[3] Idem, fig. 24.

Calycites sexpartitus Berry, n. sp.

Plate XXIX, figure 8.

Calyx-like organisms consisting of a central poorly preserved disk about 1 millimeter in diameter surrounded by six radiating rigid lanceolate segments about 7 millimeters in length and 1.25 millimeters in maximum width, the whole borne on a long, slender curved stalk, about 1 centimeter in length.

These peculiar specimens apparently represent persistent coriaceous floral organs of unknown affinity. Superficially they resemble the Paleozoic *Asterophyllites*. Forms of *Calycites* are known from the Raritan formation of the northern Atlantic coast, the Dakota sandstone of the West, and the Middendorf arkose member of the Black Creek formation of South Carolina, but none previously described are similar to this Tuscaloosa species.

Occurrence: Tuscaloosa formation, big gully on the Snow place, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Carpolithus floribundus Newberry.

Plate XXIX, figure 1.

Carpolithus floribundus Newberry, U. S. Geol. Survey Mon. 26, p. 133, pl. 46, figs. 17–21, 1896.

Hollick, The Cretaceous flora of southern New York and New England, p. 110, pl. 7, figs. 20, 21, 1906.

Berry, New Jersey Geol. Survey Bull. 3, p. 216, 1911.

Capsules (?) broadly ovate in outline and elliptical in cross section (probably as a result of compression during fossilization), in size ranging from 5 to 8 millimeters in length by 3 to 6 millimeters in diameter. They seem to be dehiscent and they are five-valved according to Newberry. I am not sure that this dehiscence may not be a result of compression, for some of them are preserved entire, and then they have a pointed apex. They occur singly or in pairs, and Newberry figured one specimen in which the axis is apparently dichotomously branched. In some specimens there are traces of what appear to be persistent calyx lobes.

These objects occur in considerable abundance in the middle part of the Raritan formation of New Jersey and somewhat doubtfully identified specimens are recorded by Hollick from the Magothy formation on Marthas Vineyard. They are not uncommon in the basal clays of the Tuscaloosa formation near Shirleys Mill. Their botanic relationship is unknown, although they suggest various modern members of the orders Geraniales, Rhamnales, and Parietales.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collections: U. S. National Museum; the types are at the New York Botanical Garden.

Carpolithus tuscaloosensis Berry, n. sp.

Fruits of unknown affinity, disk shaped, about 1 centimeter in diameter by about 3 millimeters thick, one surface comparatively flat, the other elevated. Edges thin. Peduncle in center of one side.

These peculiar fruits are given a name because of their abundance in the lower part of the Tuscaloosa formation. They are of unknown affinity, were previously undescribed, and are unlike any fruits known to me, although they suggest those of the genus *Paliurus*. They are doubtless more or less flattened, but it is believed that in life they were disk-shaped rather than spherical, for several show a peduncular scar in the center of the disk. If they had been drupelike their natural position of rest would have been with stalk on one side at or near the flattened edge. They were of considerable consistency, for they are represented when fossilized by a compact button of structureless lignite.

Occurrence: Tuscaloosa formation, big gully on the Snow place; roadside southwest of Northport; near Jones Ferry, Black Warrior River, Tuscaloosa County, Ala.

Collection: U. S. National Museum.

Phyllites shirleyensis Berry, n. sp.

Plate XXIX, figure 3.

Leaf of relatively small size, broadly lanceolate in general outline, with an acutely pointed, not extended apex and a similarly acutely pointed, somewhat decurrent base. Length about 4 centimeters. Maximum width, midway between the apex and the base, about 1.7 centimeters. Margins entire. Texture subcoriaceous. Petiole elongated, stout, and curved, about 3.5 centimeters in length. Midrib slender. Secondaries very thin, mostly immersed, parallel with the lower lateral margins, camptodrome.

This is a form of unknown botanic affinity, apparently not previously described. It is unfortunately based on the single specimen figured.

Occurrence: Tuscaloosa formation, Shirleys Mill, Fayette County, Ala.

Collection: U. S. National Museum.

Phyllites pistiaeformis Berry, n. sp.

Plate XXIX, figure 2.

Leaves of small size, elliptical in general outline, with a broadly rounded apex and a cuneate decurrent base. Length about 3 centimeters. Maximum width, in middle part of the leaf, about 2 centimeters. Margins entire but somewhat irregular. Texture coriaceous. Petiole short and broad. Midrib stout proximad, becoming thin distad, curved. Secondaries thin, ascending, camptodrome, mostly immersed in the leaf substance.

These small leaves are of unknown relationship. They are named in allusion to their resemblance to the somewhat later *Pistia nordenskioldi* (Heer) Berry, which is so abundant in the Black Creek formation of North Carolina. Any close relationship is, however, entirely problematic.

Occurrence: Tuscaloosa formation, Glen Allen, Fayette County, Ala.; cut on Southern Railway, 1⅝ miles east of Iuka, Tishomingo County, Miss.

Collection: U. S. National Museum.

Halymenites major Lesquereux.

Halymenites major Lesquereux, The Tertiary flora, p. 38, pl. 1, figs. 7, 8, 1878.

These very abundant objects, frequently considered to represent fossil fucoids, are abundant in the western United States in sandy beds ranging in age from the Colorado group to the Eocene. They were long thought to be typical of the Fox Hills sandstone, in which they are abundantly developed, but are now known from both older and younger beds and characterize sandy ferruginous sediments.

Typical material is abundant in the Coffee sand member of the Eutaw formation and also at different horizons in the Ripley formation in western Tennessee. Generally, however, these objects are very friable, and the collected specimens represent only the beds enumerated below.

Occurrence: Eutaw formation (Coffee sand member), Coffee Bluff, Hardin County, Tenn. Ripley formation (McNairy sand member), McNairy County, Tenn.

Collection: Johns Hopkins University.

Phyllites asplenioides Berry, n. sp.

Plate XXXIII, figures 1-3.

Fronds large in size, lax in habit but apparently of a thinly coriaceous texture. Apparently entire or with only a shallowly lobate margin. Reniform or broadly obovate in outline. Minimum length and width, over 15 centimeters. Midrib consisting of a wide, flat mass of veins formed by the approximation and subparallel proximad course of all the veins of the frond. These veins are numerous, diverge at acute angles and fork dichotomously two or three times, most of the dichotomies being near the point of their divergence. Thenceforth they are mostly subparallel, here and there coalescing to form a much-elongated netted venation.

This peculiar form is so striking a type and one moreover so totally unlike anything that I have encountered in the Upper Cretaceous that it can not be omitted from any discussion of our Upper Cretaceous floras, although its botanic affinity is more or less problematic.

Certain beds in the clays of the Eutaw formation at Coffee Bluff are packed with the broken remains of these fronds, and it has been impossible to determine conclusively their exact size and form. Two of the most complete specimens are figured on the accompanying plate. The apparently flabellate segments appear to be the result of splitting and most of them are clearly due to slight offsets in the clay after deposition. Only three possible botanic relationships seem suggestive. The material might represent some lax monocotyledonous leaf of unknown affinity similar to *Nitophyllum beaumontanum* described by Bureau[1] from the Lutetian of France; it might represent some hitherto unknown type of Mesozoic cycadophyte; or it may be a true pteridophyte. I incline to the interpretation that it represents the simple tufted fronds of a gigantic asplenioid fern like some of the modern forms referred to *Diplazium* or to the large and reniform fronded existing scolopendriums of the section *Schaffneria* of Fée, such as *Scolopendrium delavayi* Franch, of the mountains of Farther India and Yunnan, or *Scolopendrium nigripes* (Fée) Hooker, of southern Mexico and Guatemala. Rather similar but equally indefinite remains were described from the Eocene at Green River, Wyo., and named by Lesquereux[1] *Musophyllum complicatum* from their fancied resemblance to the leaves of the existing monocotyledonous genus *Musa*.

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[1] Bureau, E., Études sur la flore fossile du calcaire grossier parisien, p. 235, 1888. Considered of an algal nature by this author.

The present material comes from a slightly higher clay lens in the Coffee sand than that from which the remainder of the Coffee Bluff plants were obtained and was collected by Bruce Wade in the autumn of 1916.

Occurrence: Eutaw formation (Coffee sand member), Coffee Bluff, Hardin County, Tenn.

Collection: Johns Hopkins University.

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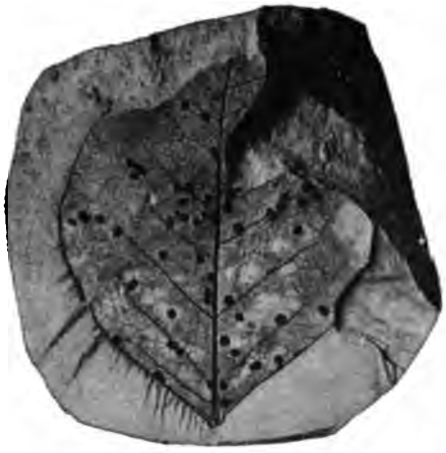
[1] Lesquereux, Leo, The Tertiary flora, p. 96, pl. 15, figs. 1-6, 1878.

PLATES V-XXXIII.

PLATE V.

	Page.
FIGURE 1. *Sphaerites alabamensis* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34794).	49
FIGURES 2, 3. *Jungermannites cretaceus* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34795–34796)	49
FIGURES 4–7. *Lycopodites tuscaloosensis* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34797–34800)	50
FIGURE 8. *Cladophlebis alabamensis* Berry, from gully on Snow place, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34801)	51
FIGURE 9. *Brachyphyllum macrocarpum formosum* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34802)	59

All specimens are from the Tuscaloosa formation.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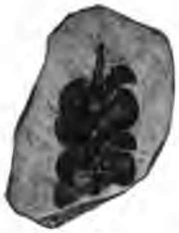
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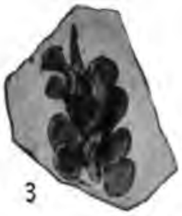
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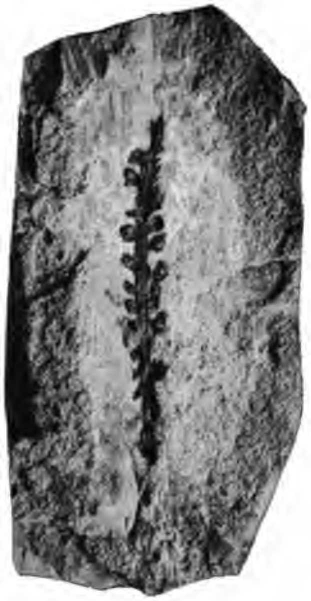
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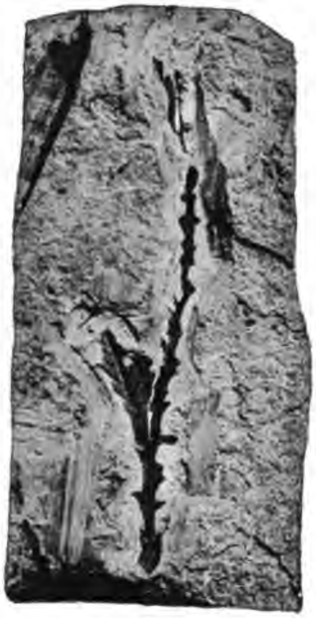
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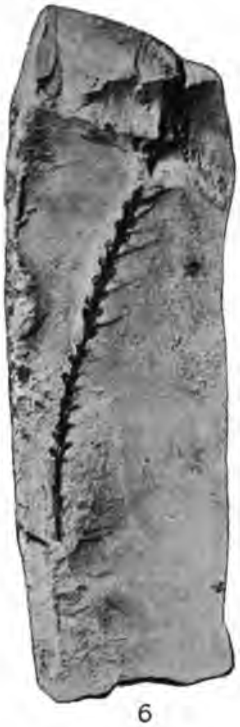
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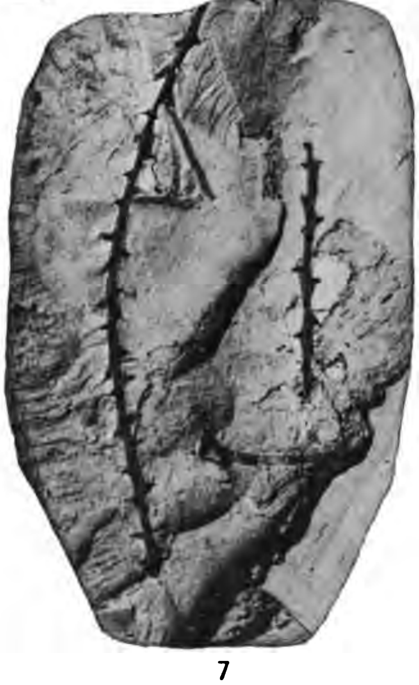
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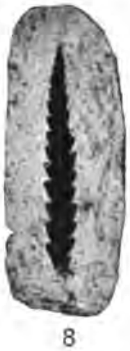
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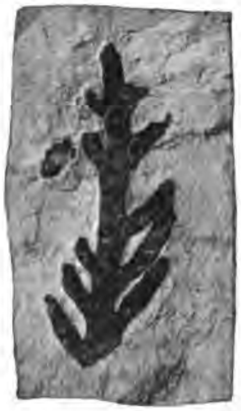
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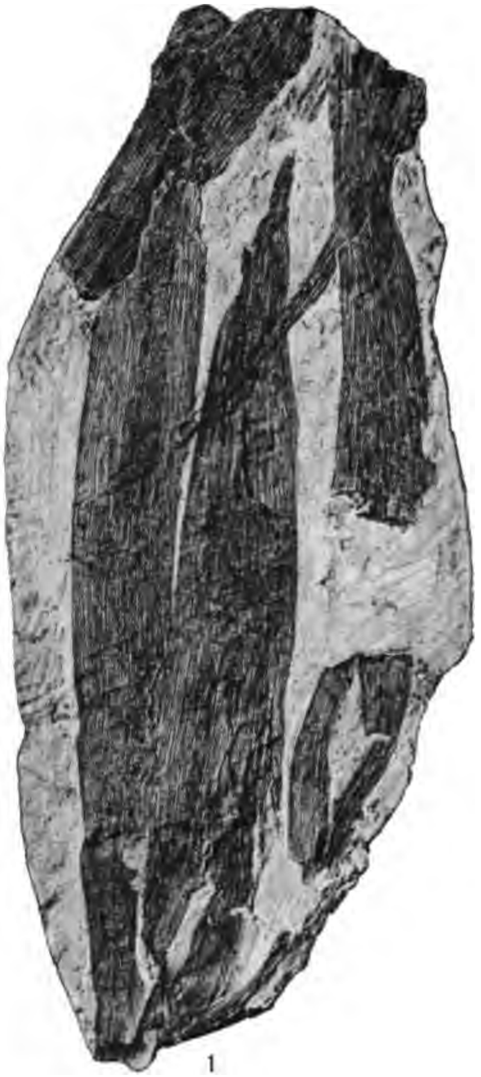
FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.



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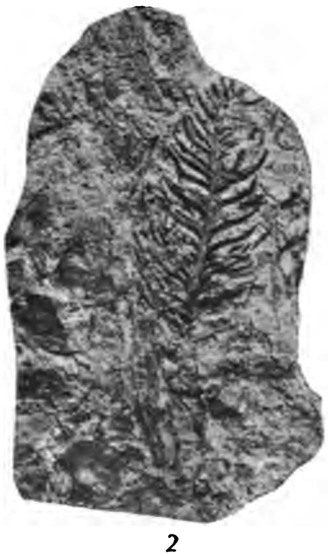

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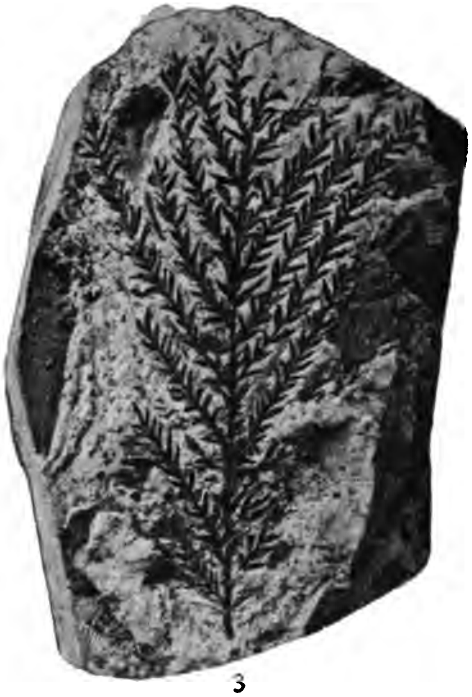

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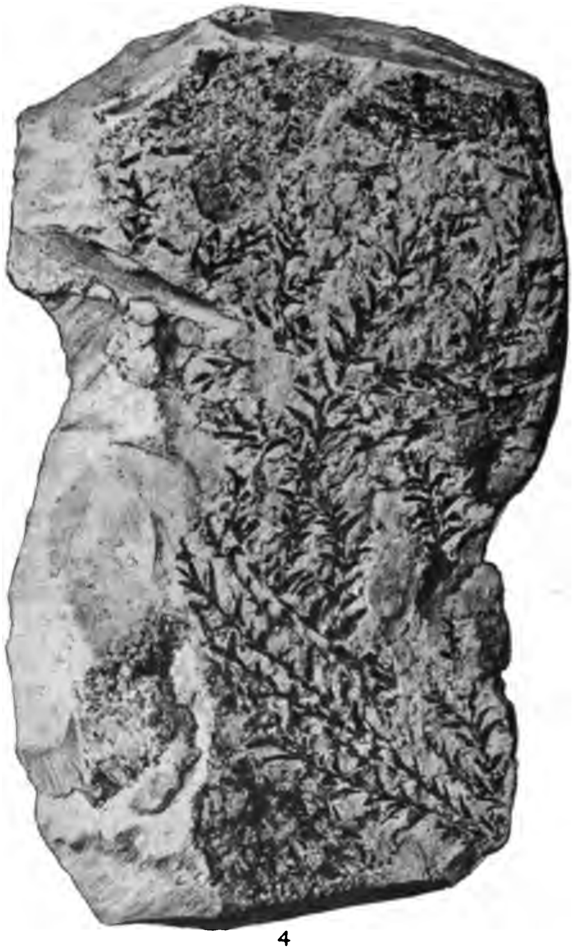


4

FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE VI.

Page.

FIGURE 1. *Podozamites marginatus* Heer, from the Tuscaloosa formation in gully on Snow place, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34803).. 55

FIGURE 2. *Sequoia reichenbachi* (Geinitz) Heer, from the Eutaw formation at Havana, Hale County, Ala. (U. S. Nat. Mus. Cat. No. 34804).. 64

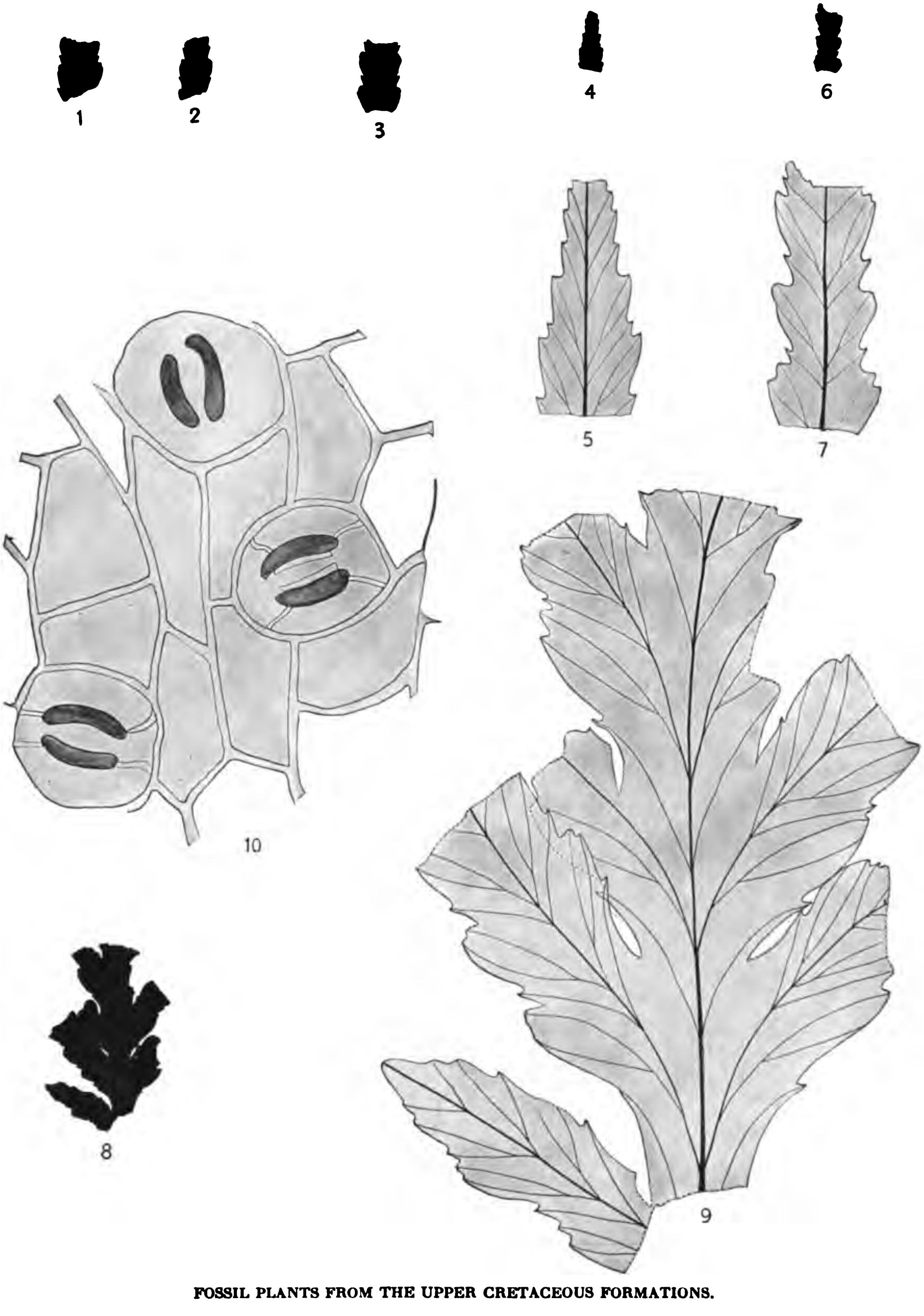
FIGURES 3, 4. *Sequoia ambigua* Heer (U. S. Nat. Mus. Cat. Nos. 34805–34806)................................ 66

3. Specimen from the Eutaw formation at Havana, Hale County, Ala.
4. Specimen from the Tuscaloosa formation in gully on Snow place, Tuscaloosa County, Ala.

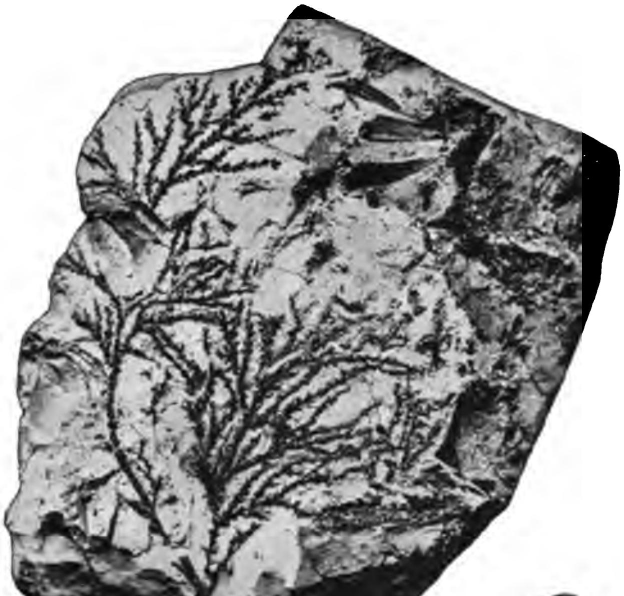
PLATE VII.

		Page.
Figures 1-10.	*Androvettia carolinensis* Berry	62

1–3. Fragments of foliage from the Tuscaloosa formation in Tishomingo County, Miss., natural size. (U. S. Nat. Mus. Cat. Nos. 34807–34809).
4. Fragment from the Black Creek formation of North Carolina, natural size.
5. Specimen shown in figure 4, × 4.
6. Another small specimen from North Carolina, natural size.
7. Specimen shown in figure 6, × 4.
8. A larger twig from North Carolina, natural size.
9. Specimen shown in figure 8, × 4.
10. Photomicrograph showing epidermal cells and stomata, × 385.



FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.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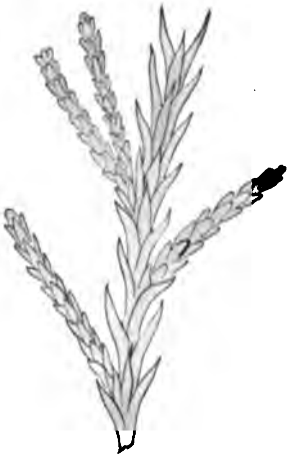
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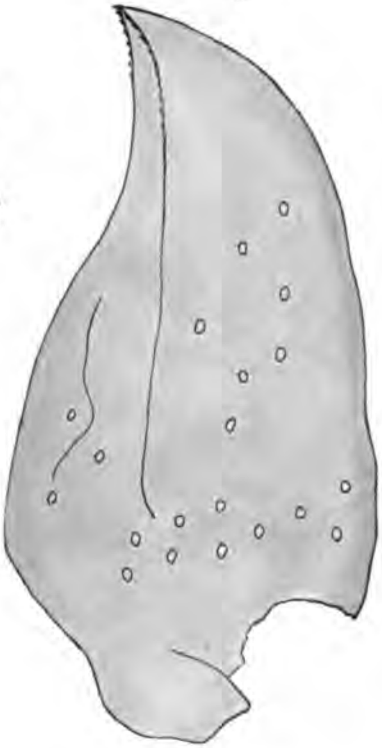
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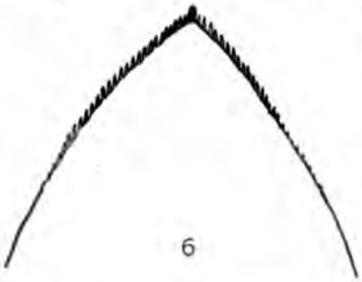
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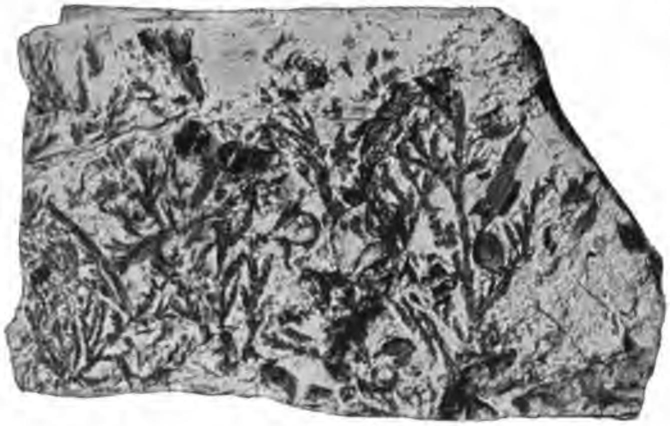
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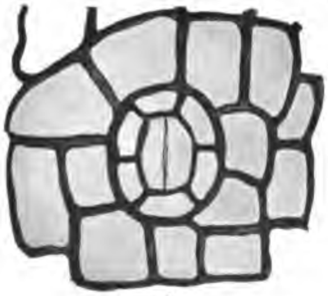
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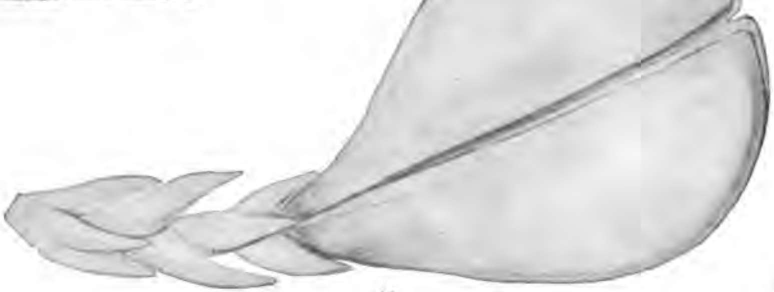
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FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

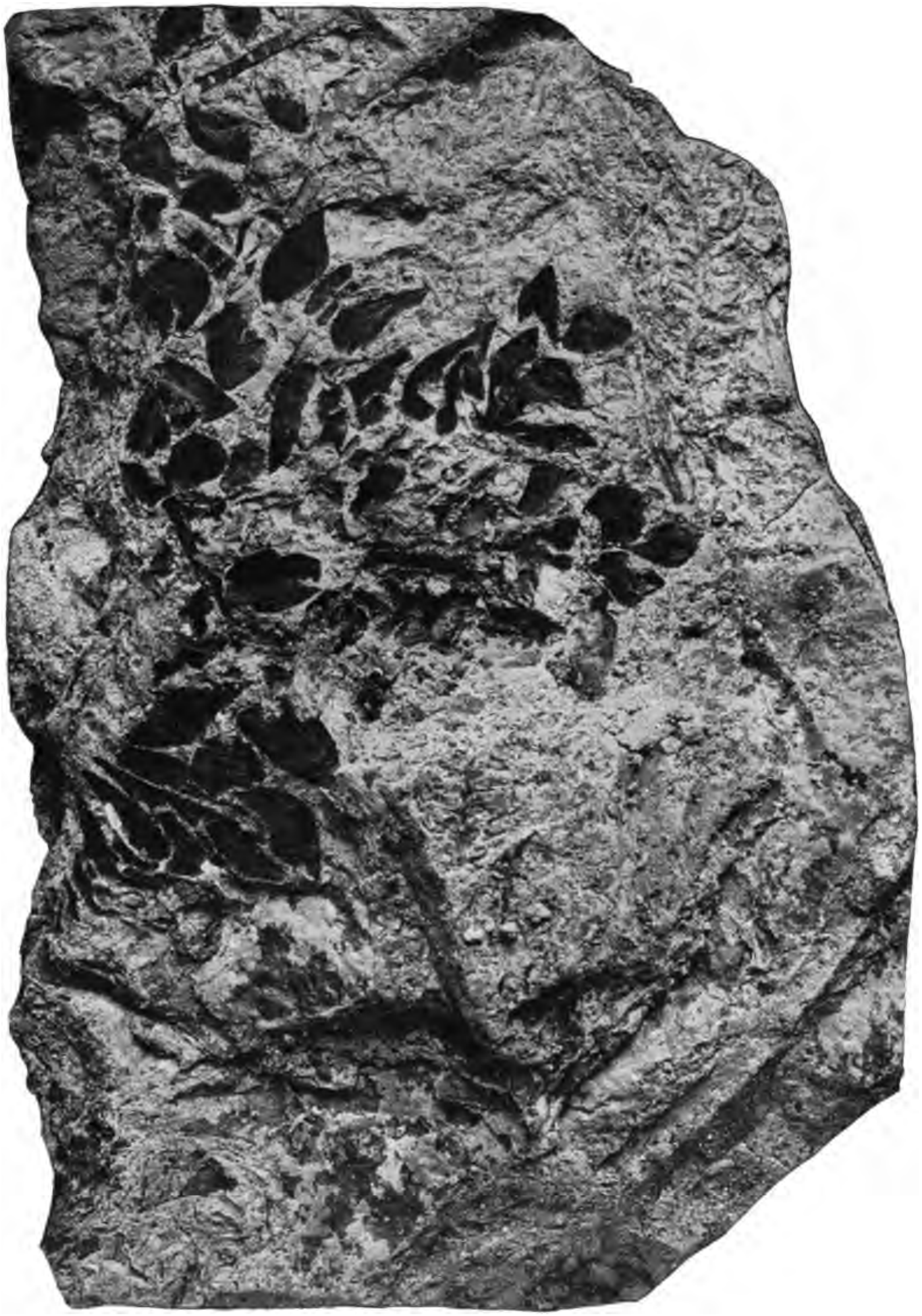
PLATE VIII.

		Page.
FIGURES 1-12.	*Widdringtonites subtilis* Heer, from the Tuscaloosa formation of Alabama	67

1. Specimen from gully on Snow place, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34810).
2. Twig from specimen illustrated in figure 1, showing dimorphism, × 5.
3. Terminal-flattened twig from gully on Snow place, Tuscaloosa County, Ala., × 5 (U. S. Nat. Mus. Cat. No. 34811).

4, 5. Leaves from same, × 10 (U. S. Nat. Mus. Cat. Nos. 34812, 34813).

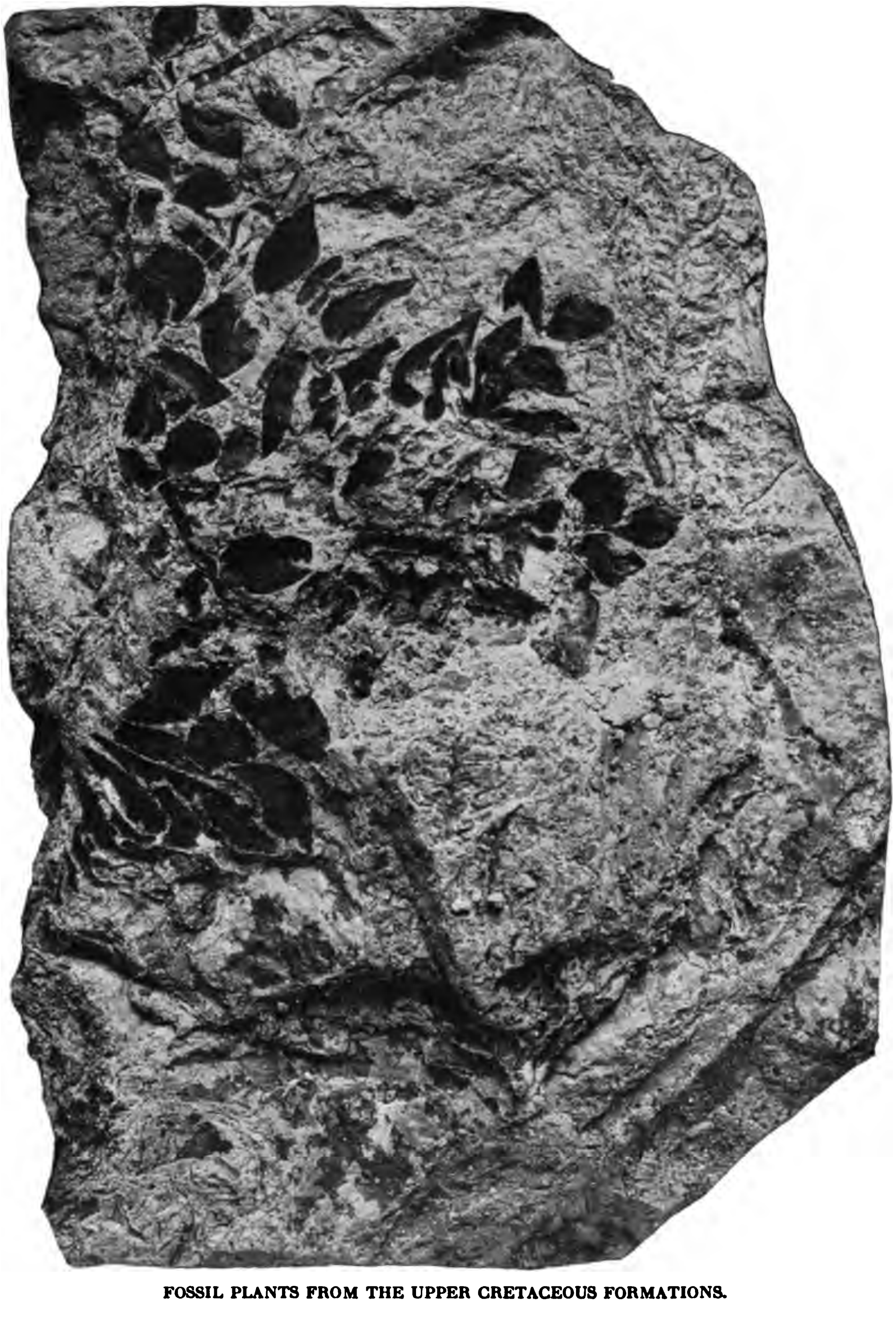
6. Sketch of tip of leaf illustrated in figure 5 showing marginal spines, × 50.
7. Another leaf, × 10 (U. S. Nat. Mus. Cat. No. 34814).
8. Sketch of leaf illustrated in figure 7 showing location of stomata, × 50.
9. Drawing of epidermal preparation from preceding (fig. 8) showing stoma, × 205.
10. Specimen from Shirleys Mill, Fayette County, Ala., with elongated leaves (U. S. Nat. Mus. Cat. No. 34815).
11. Cone-bearing specimen from gully on Snow place, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34816).
12. Cone from specimen shown in figure 11, × 10.



FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE X.

	Page.
Araucaria bladenensis Berry, from the Eutaw formation at Havana, Hale County, Ala. (U. S. Nat. Mus. Cat. No. 34818)	61



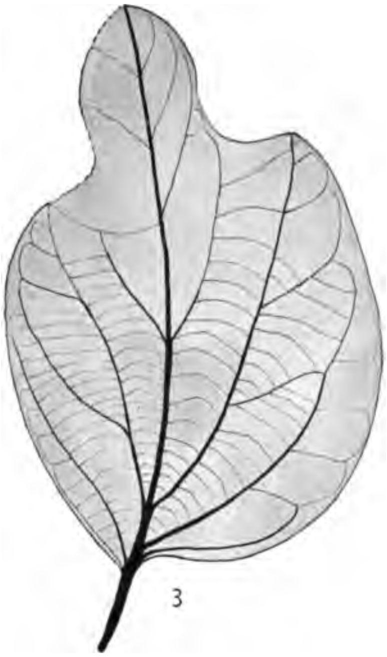
FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE X.

	Page.
Araucaria bladenensis Berry, from the Eutaw formation at Havana, Hale County, Ala. (U. S. Nat. Mus. Cat. No. 34818)	61

PLATE XI.

	Page.
FIGURE 1. *Sabalites* sp. Berry, from the Ripley formation at Camden, Tenn. (U. S. Nat. Mus. Cat. No. 34819).	72
FIGURE 2. *Myrica ripleyensis* Berry, from the Ripley formation 13 miles northwest of Camden, Benton County, Tenn. (U. S. Nat. Mus. Cat. No. 34820)	74
FIGURE 3. *Ficus fontainii* Berry, from the Tuscaloosa formation at Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34821)	82
FIGURE 4. *Myrcia havanensis* Berry, from the Ripley formation at Camden, Benton County, Tenn. (U. S. Nat. Mus. Cat. No. 34822)	125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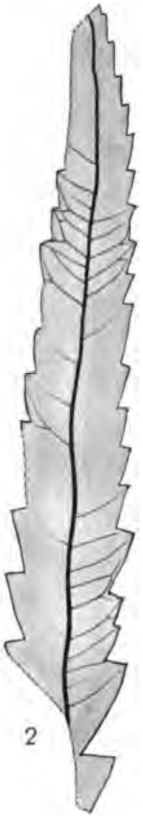
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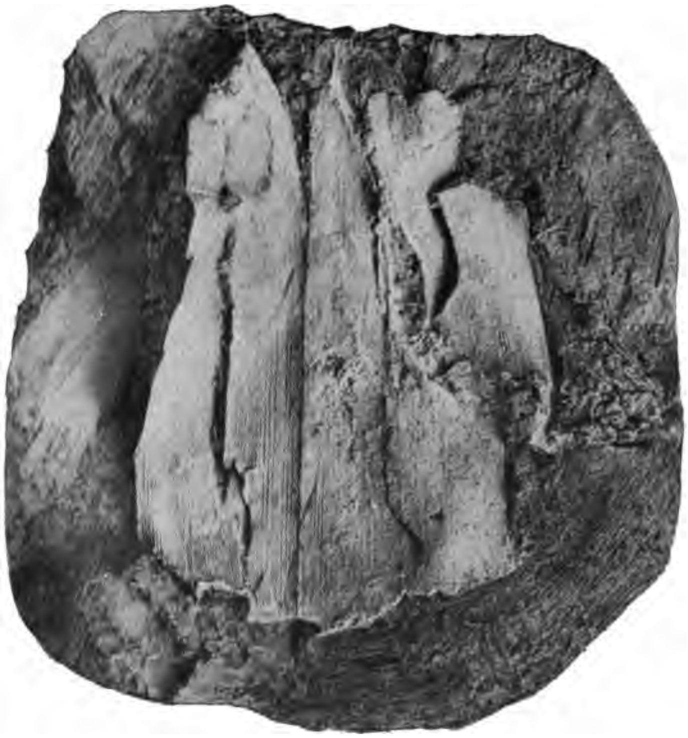
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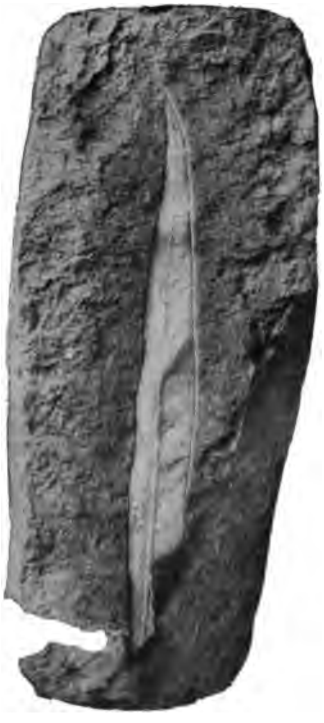
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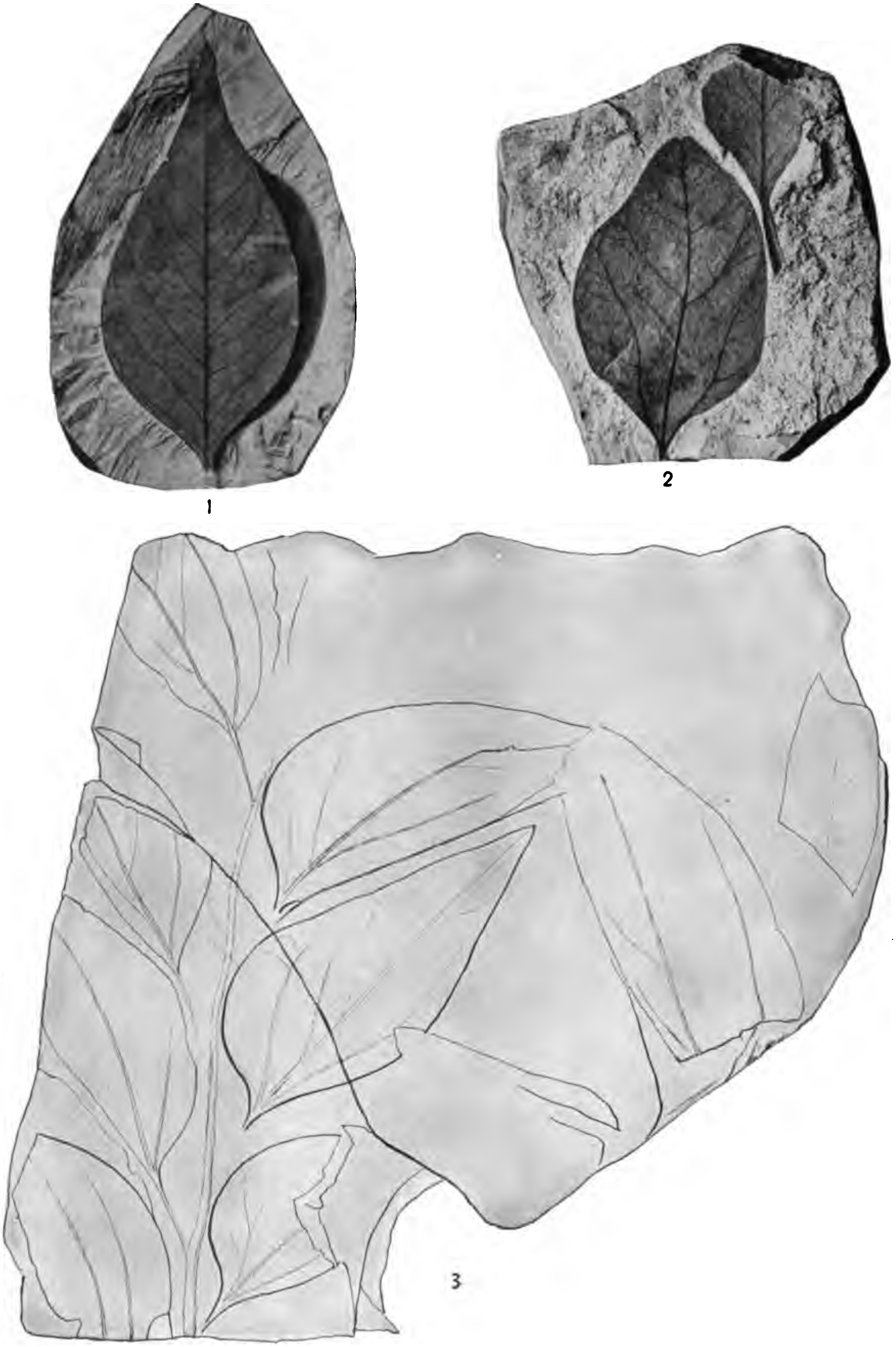
FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.



FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE XII.

		Page.
Figure 1.	*Ficus inaequalis* Lesquereux, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34823)	80
Figure 2.	*Ficus woolsoni* Newberry, from Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34824).	81
Figure 3.	*Piperites tuscaloosensis* Berry, from Tuscaloosa, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34825)	72

All specimens are from the Tuscaloosa formation.

PLATE XIII.

Page.

Figure 1. *Doryanthites cretacea* Berry, from the Eutaw formation at Havana, Hale County, Ala. (U. S. Nat. Mus. Cat. No. 34826) 70

Figure 2. *Populites tuscaloosensis* Berry, from the Tuscaloosa formation at Glen Allen Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34827) 77

Figure 3. *Salix flexuosa* Newberry, from the Tuscaloosa formation at Maplesville, Chilton County, Ala. (U. S. Nat. Mus. Cat. No. 34828) 75

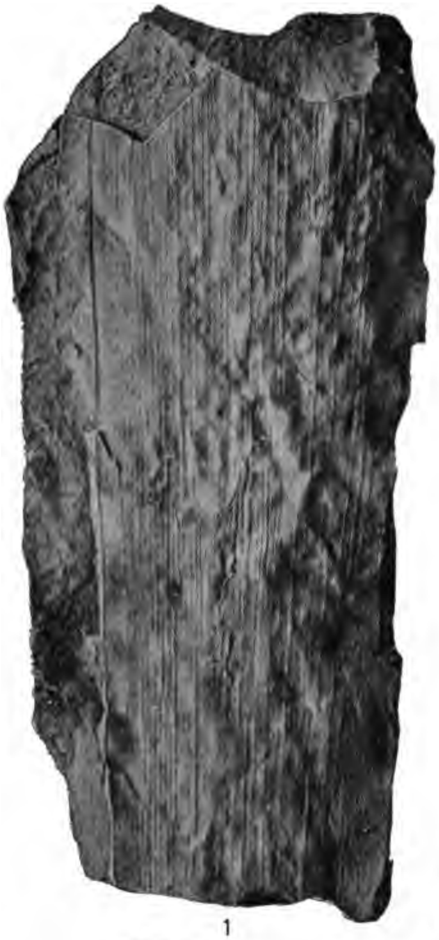
Figure 4. *Myrica emarginata* Heer, from the Tuscaloosa formation at Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34829) 73

Figure 5. *Myrica dakotensis minima* Berry, from the Tuscaloosa formation at Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34830) 74

Figure 6. *Ficus daphnogenoides* (Heer) Berry, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34831) 80

Figure 7. A small form of the same species from the Tuscaloosa formation at Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34832) 80

Figure 8. *Ficus shirleyensis* Berry, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34833) 81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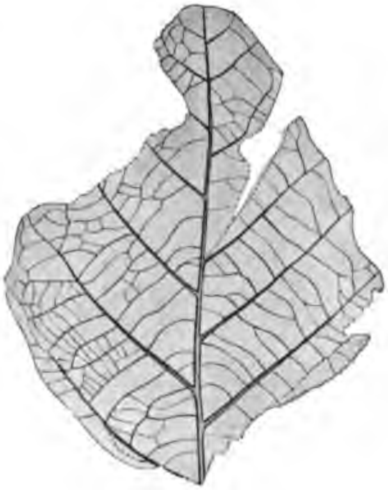
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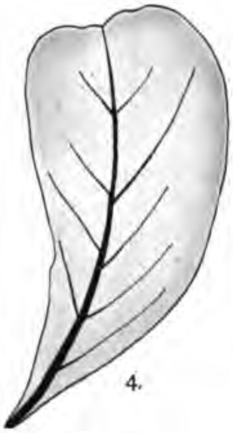
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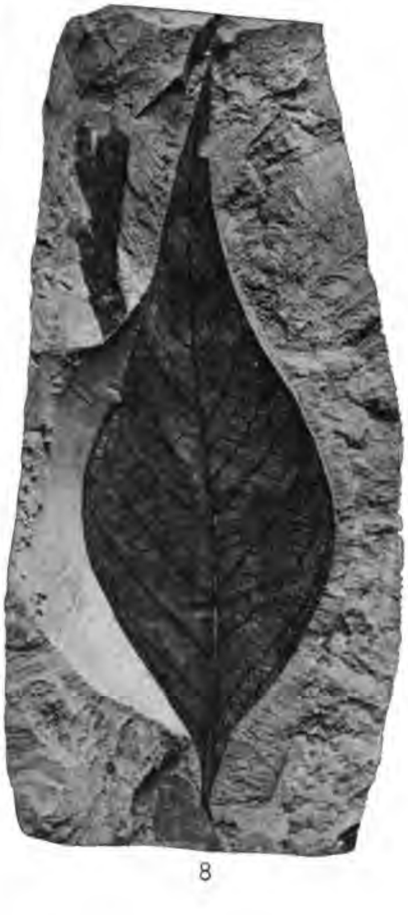
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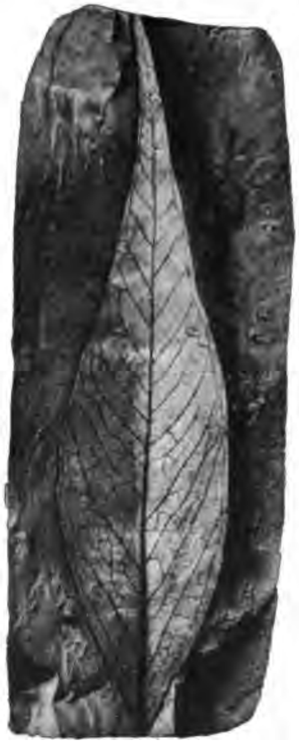
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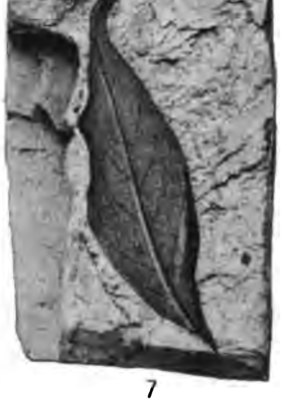
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FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE XIII.

Page.

FIGURE 1. *Doryanthites cretacea* Berry, from the Eutaw formation at Havana, Hale County, Ala. (U. S. Nat. Mus. Cat. No. 34826) 70

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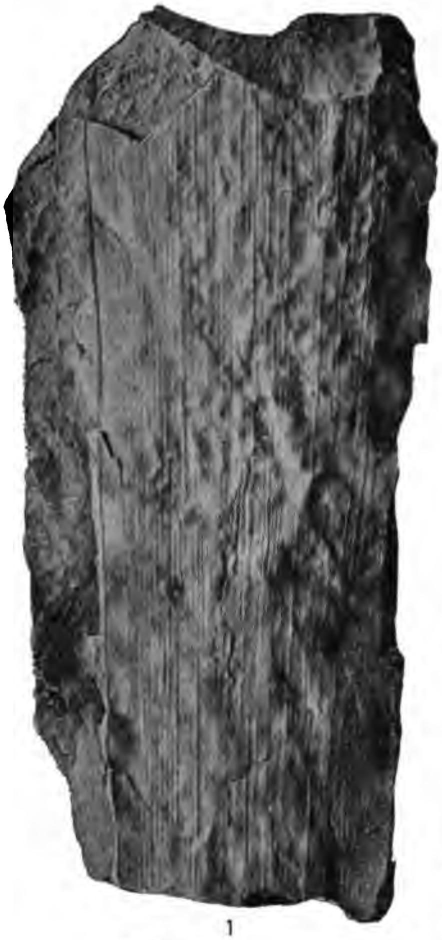
FIGURE 4. *Myrica emarginata* Heer, from the Tuscaloosa formation at Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34829) 73

FIGURE 5. *Myrica dakotensis minima* Berry, from the Tuscaloosa formation at Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34830) 74

FIGURE 6. *Ficus daphnogenoides* (Heer) Berry, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34831) 80

FIGURE 7. A small form of the same species from the Tuscaloosa formation at Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34832) 80

FIGURE 8. *Ficus shirleyensis* Berry, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34833) 81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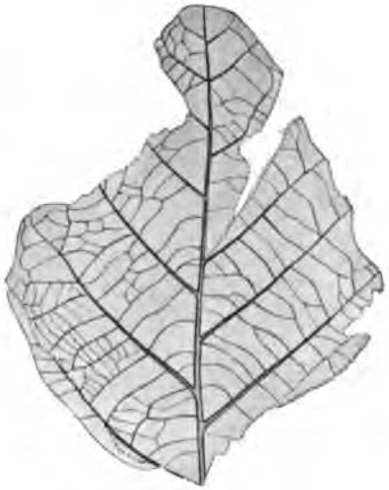
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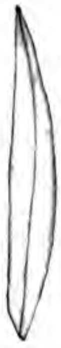
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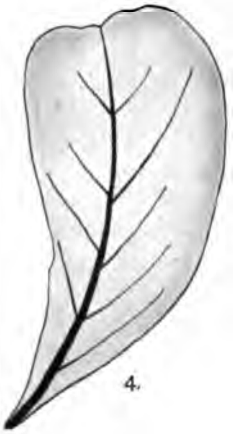
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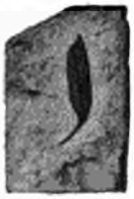
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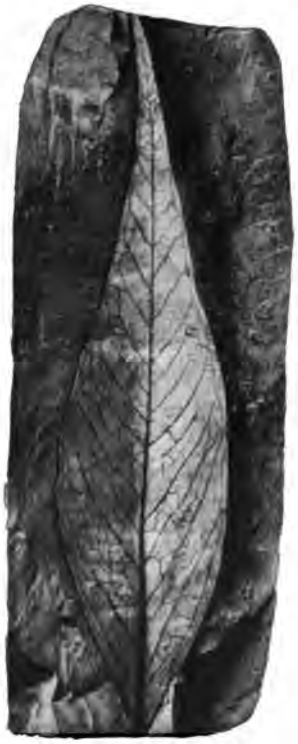
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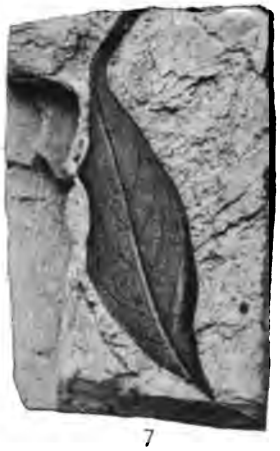
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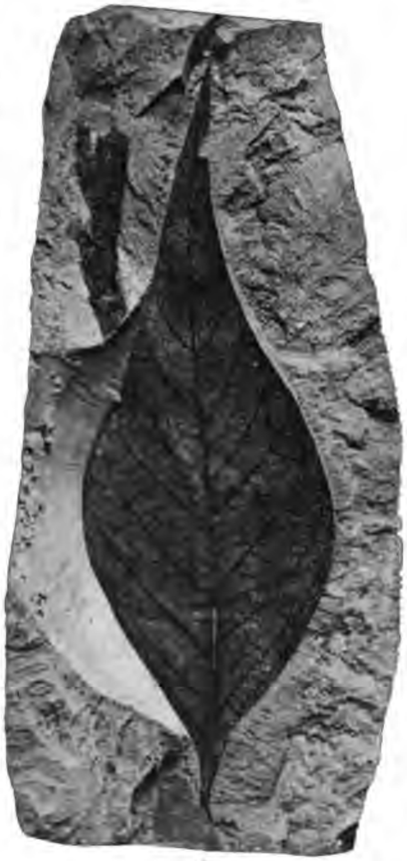
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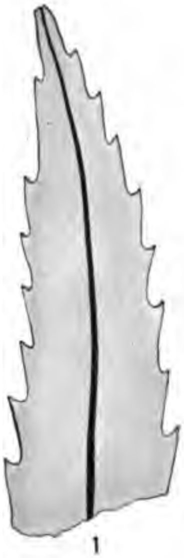
FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.



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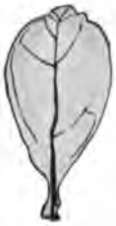

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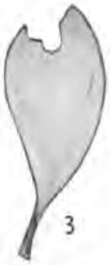

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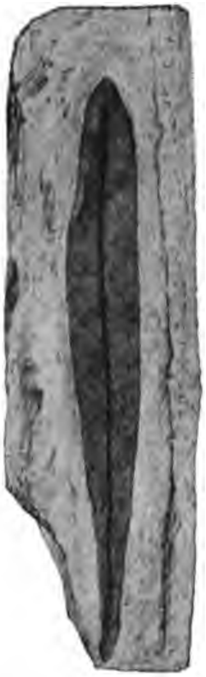

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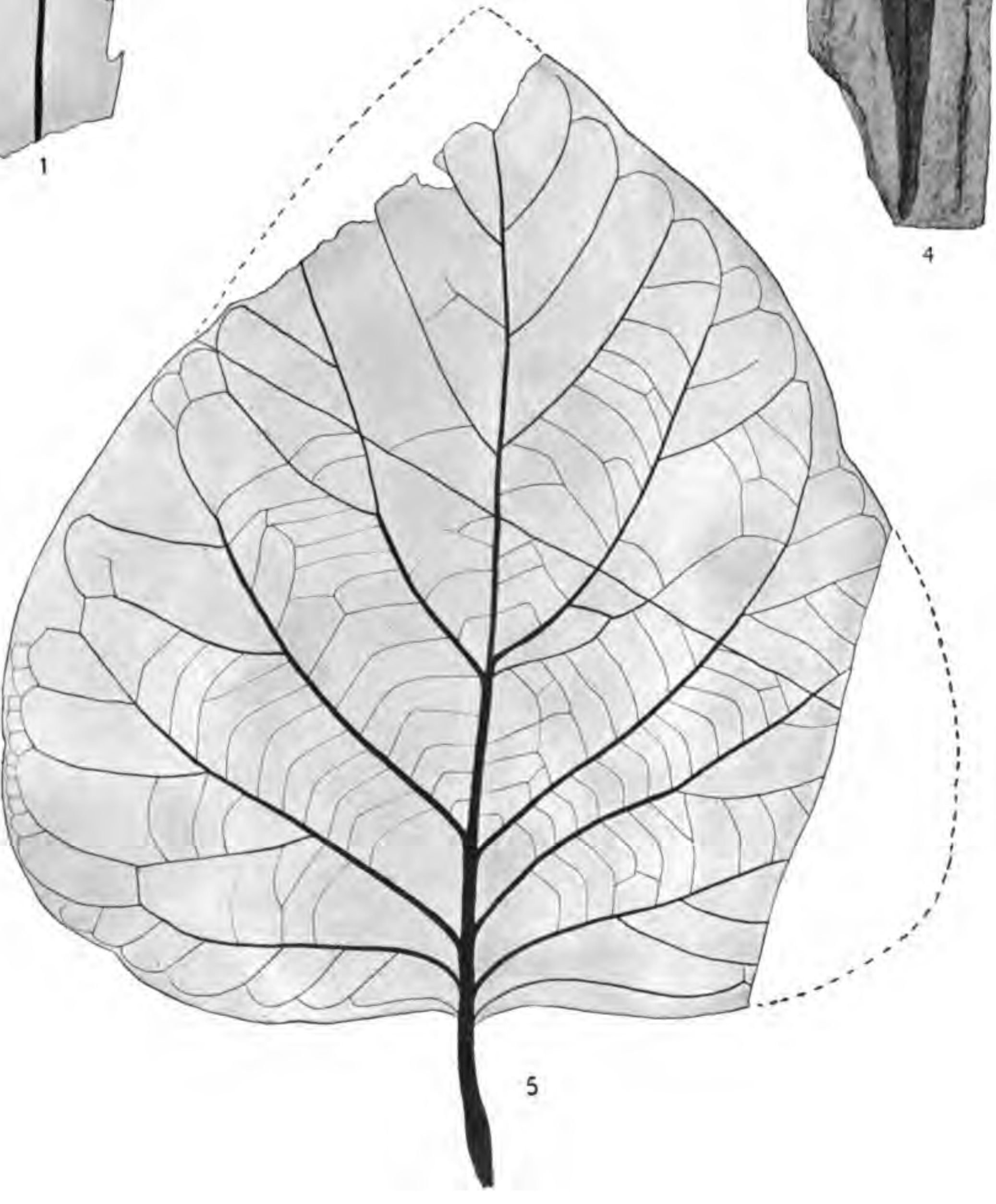

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FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE XIV.

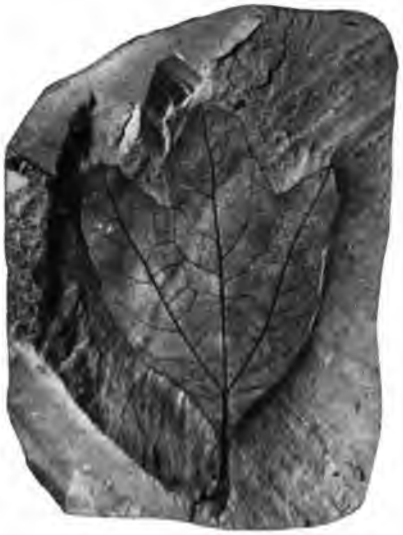
	Page.
FIGURE 1. *Dewalquea smithi* Berry, from Whites Bluff, Greene County, Ala. (U. S. Nat. Mus. Cat. No. 34834)..	86
FIGURE 2. *Persoonia lesquereuxii* Knowlton, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34835)..	85
FIGURE 3. *Persoonia lesquereuxii minor* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34836)..	86
FIGURE 4. *Proteoides conospermaefolia* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34837)..	85
FIGURE 5. *Ficus alabamensis* Berry, from Shirleys Mill, Fayette County Ala. (U. S. Nat. Mus. Cat. No. 34838).	82

All specimens are from the Tuscaloosa formation.

PLATE XV.

Page.

FIGURES 1–5. *Platanus shirleyensis* Berry, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34839–34843) 83



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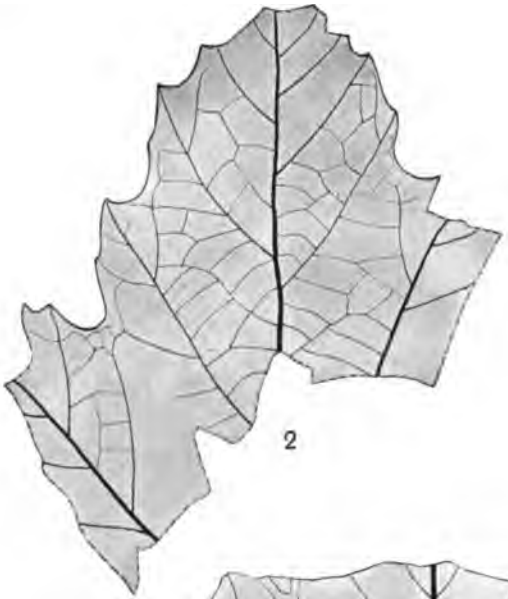

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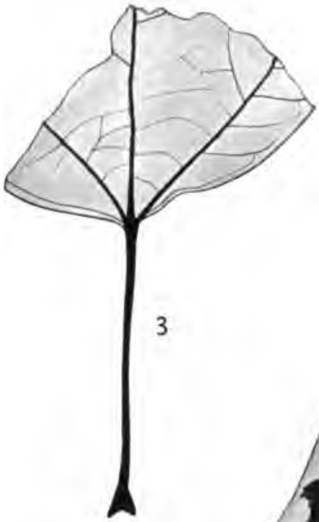

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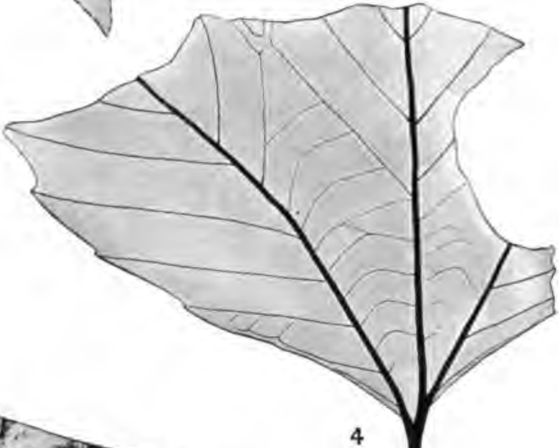

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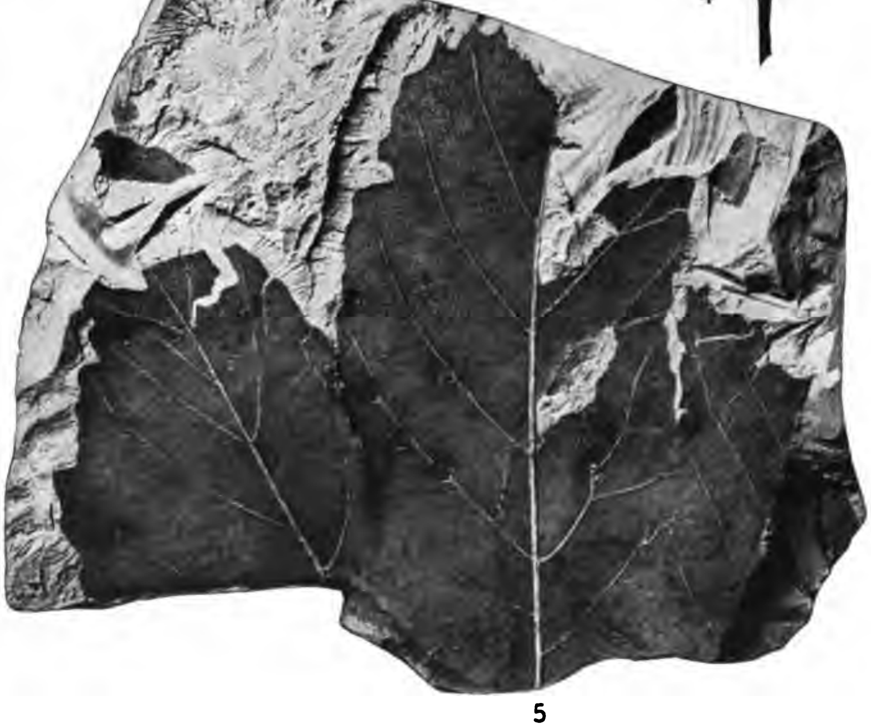

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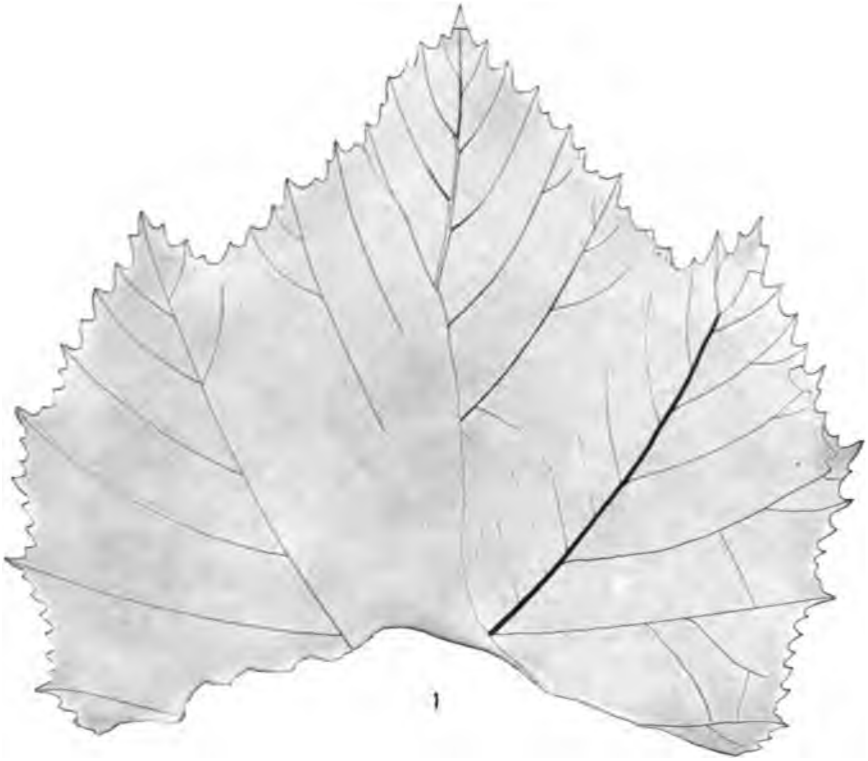
FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.



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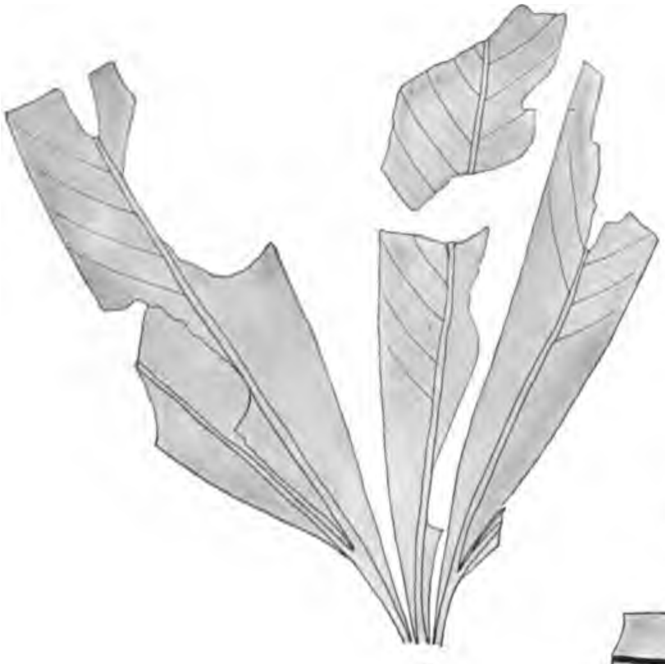

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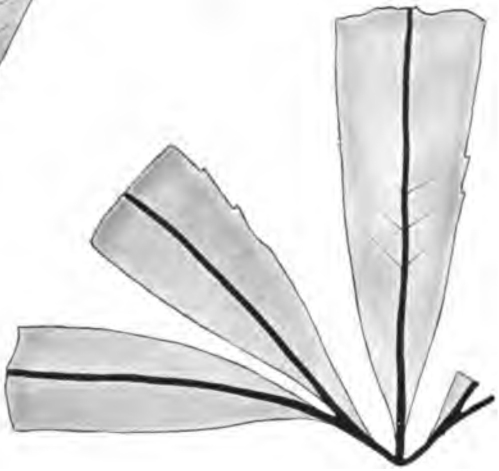


3

FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE XVI.

	Page.
FIGURE 1. *Platanus asperaeformis* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34844)	83
FIGURES 2, 3. *Dewalquea smithi* Berry, from Whites Bluff, Greene County, Ala. (U. S. Nat. Mus. Cat. Nos. 34845, 34846)	86

All specimens are from the Tuscaloosa formation.

PLATE XVII.

Page.

FIGURE 1. *Cocculus cinnamomeus* Velenovsky, from Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34847) 93

FIGURES 2, 3. *Cocculus polycarpaefolius* Berry, from Cottondale, Tuscaloosa County Ala. (U. S. Nat. Mus. Cat. Nos. 34848, 34849) 94

FIGURE 4. *Cocculus problematicus* Berry, from Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34850) 94

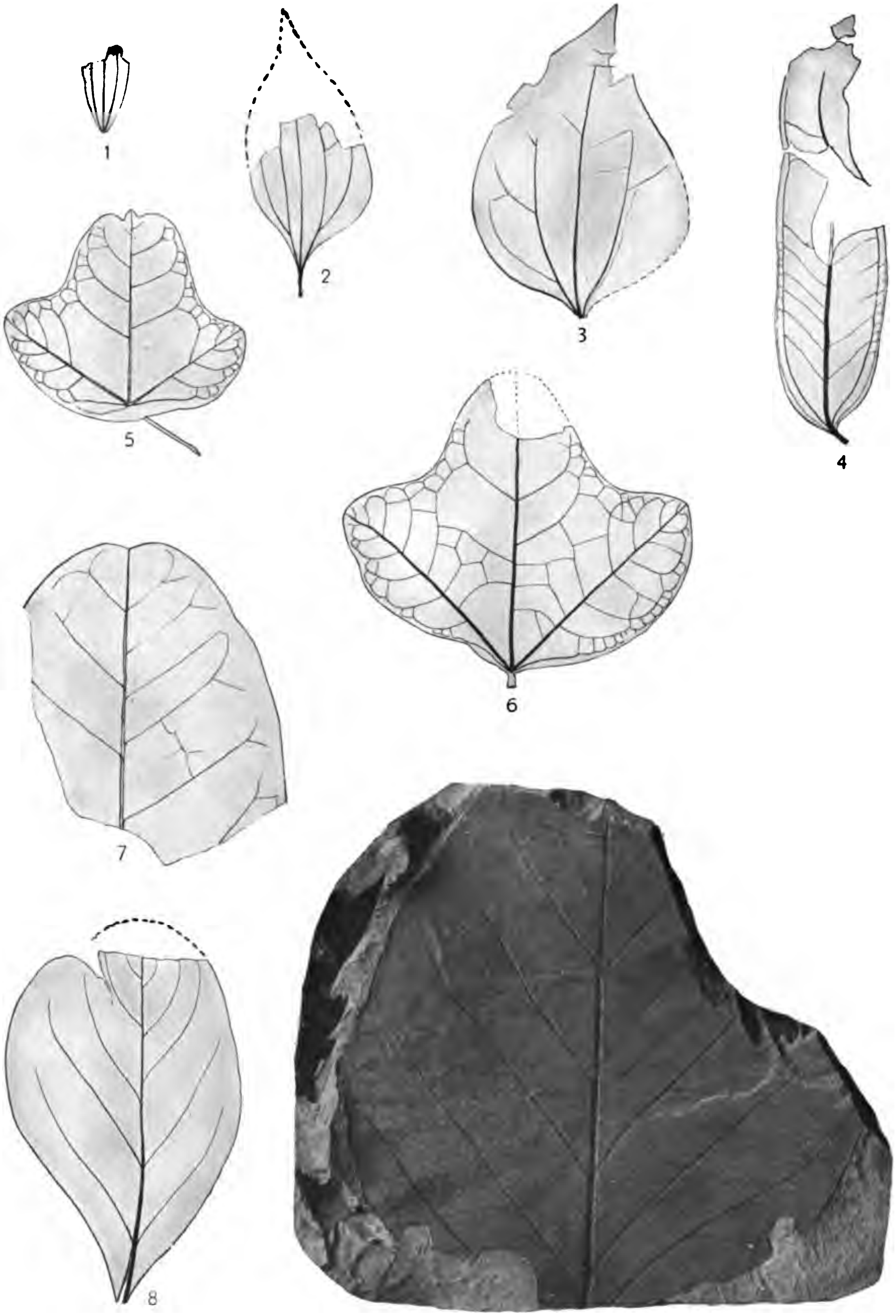
FIGURES 5, 6. *Menispermites trilobatus* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34851, 34852) 95

FIGURES 7, 8. *Magnolia obtusata* Heer 90

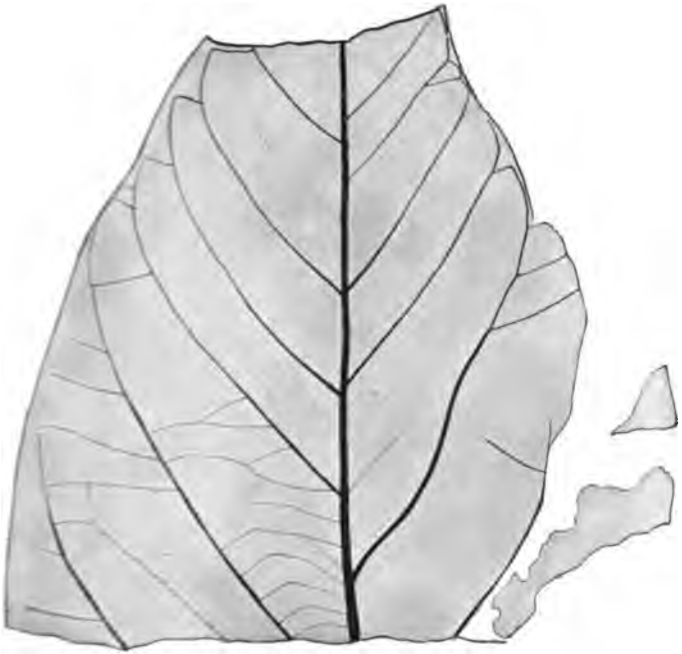
7. Specimen from Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34853).
8. Specimen from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34854).

FIGURE 9. *Magnolia lacoeana* Lesquereux, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34855) 91

All specimens are from the Tuscaloosa formation.



FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.



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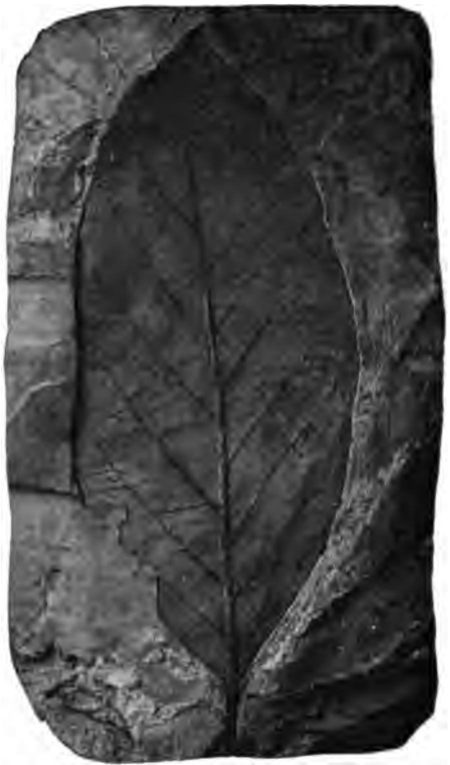

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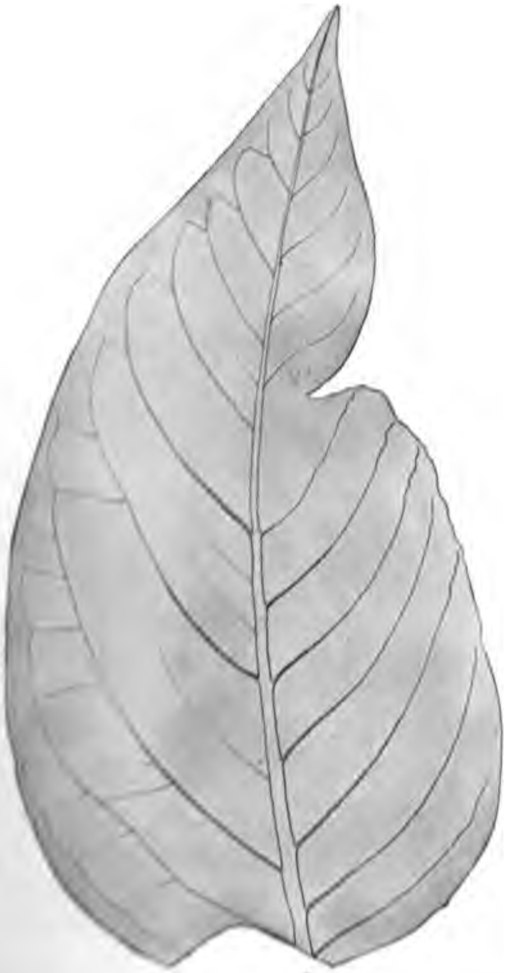

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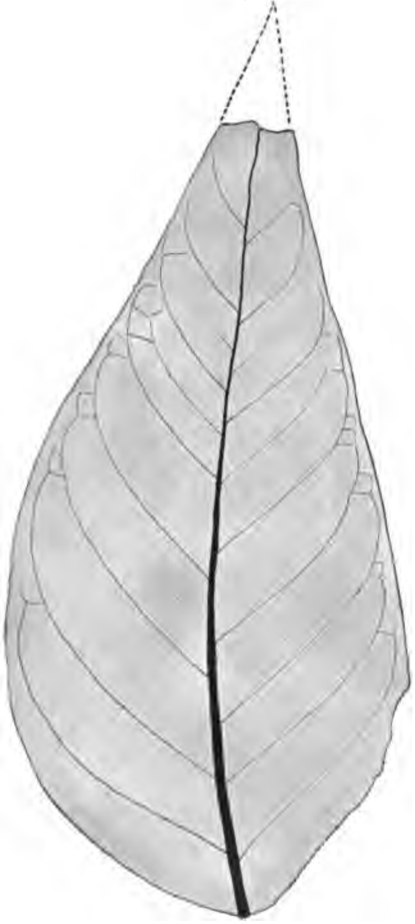


4

FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE XVIII.

Page.

FIGURE 1. *Magnolia capellinii* Heer, from Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34856). 89

FIGURE 2. *Magnolia boulayana* Lesquereux, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34857)........ 90

FIGURES 3, 4. *Magnolia speciosa* Heer........ 88

3. Specimen from Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34858).
4. Specimen from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34859).

All specimens are from the Tuscaloosa formation.

PLATE XIX.

Page.

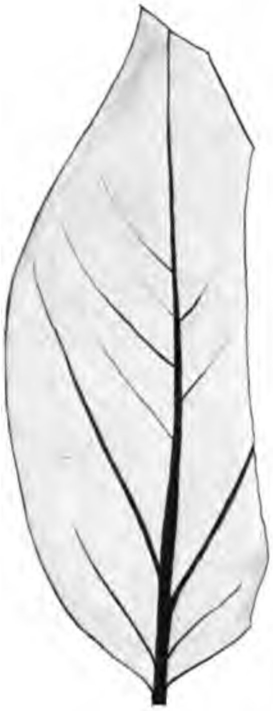
Figures 1, 2. *Oreodaphne shirleyensis* Berry, from Shirleys Mill, Fayette County Ala. (U. S. Nat. Mus. Cat. Nos. 34860, 34861) 119

Figures 3–5. *Oreodaphne alabamensis* Berry 119

3, 4. Specimen from Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. Nos. 34862 34863).

5. Restoration from specimens shown in figures 3 and 4.

All specimens are from the Tuscaloosa formation.



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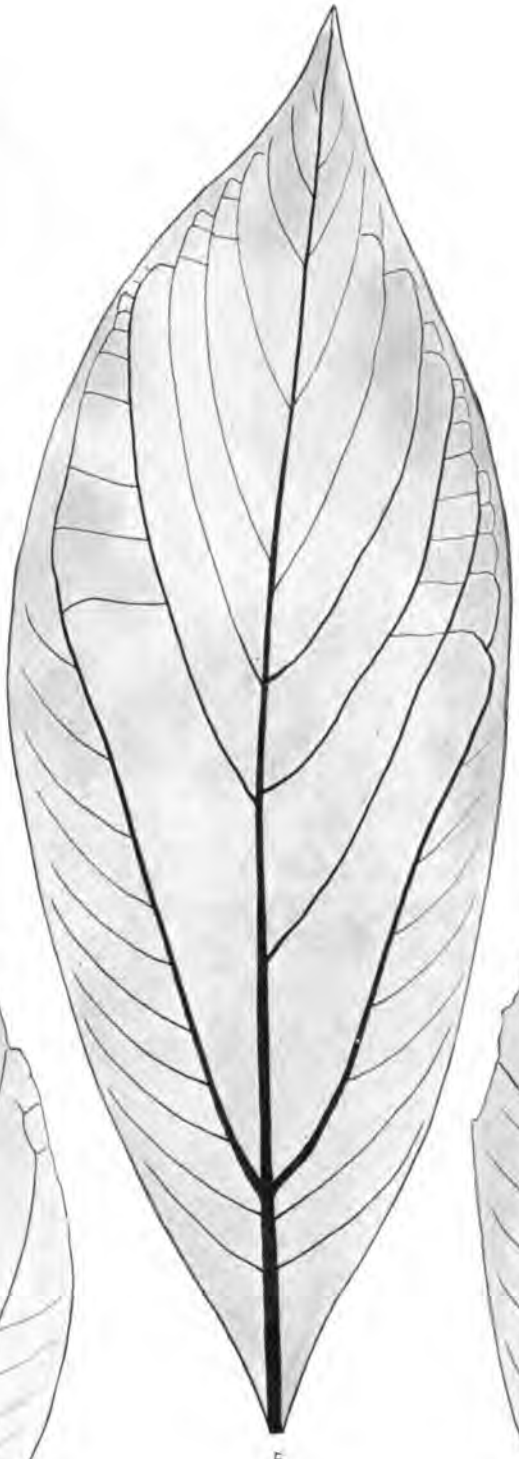

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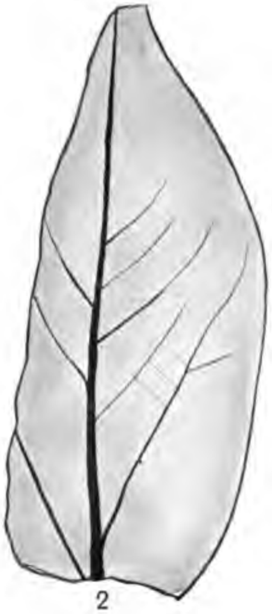

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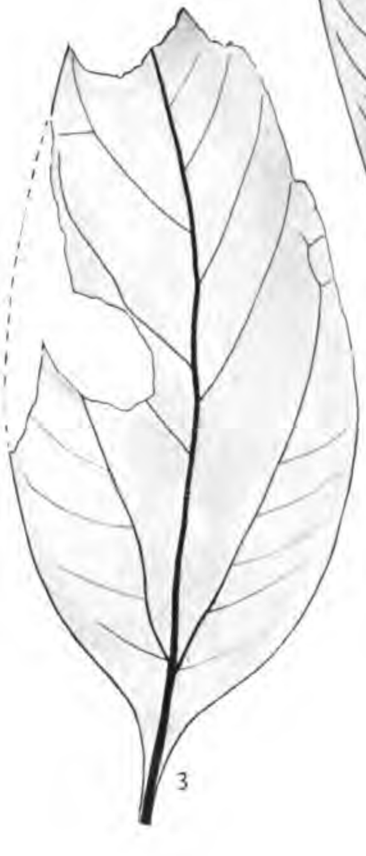

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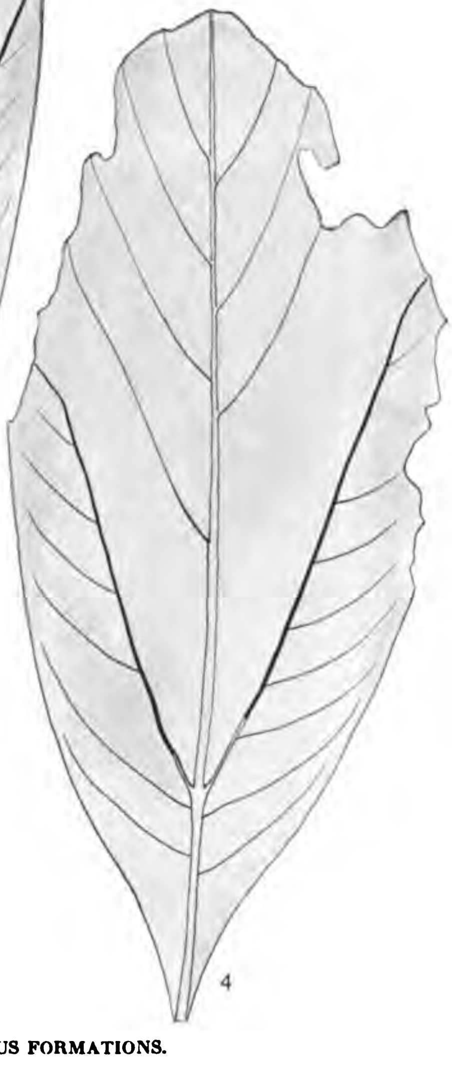

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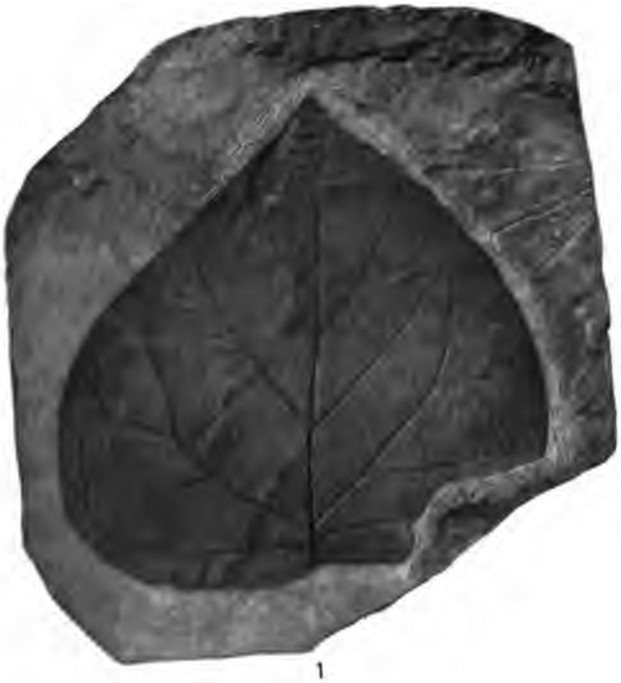
FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.



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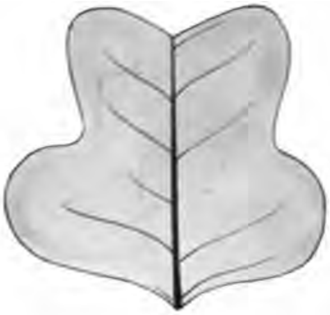

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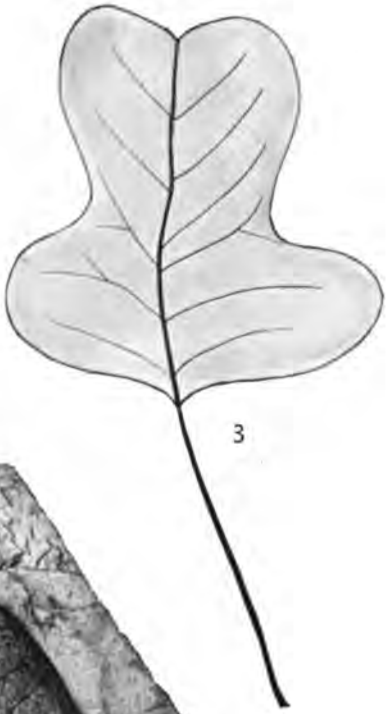

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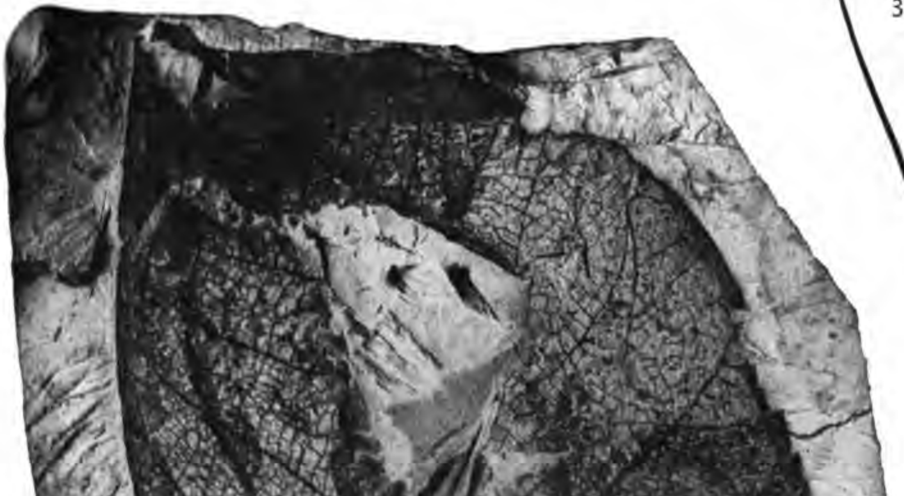

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FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE XX.

	Page.
Figure 1. *Menispermites integrifolius* Berry, from Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34864)	94
Figure 2. *Liriodendron meekii* Heer, from Cottondale, Tuscaloosa County, Ala. (type crushed)	92
Figure 3. *Liriodendron tulipifera* Linné, a living form, introduced for comparison.	
Figure 4. *Magnolia newberryi* Berry, from Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34865)	89

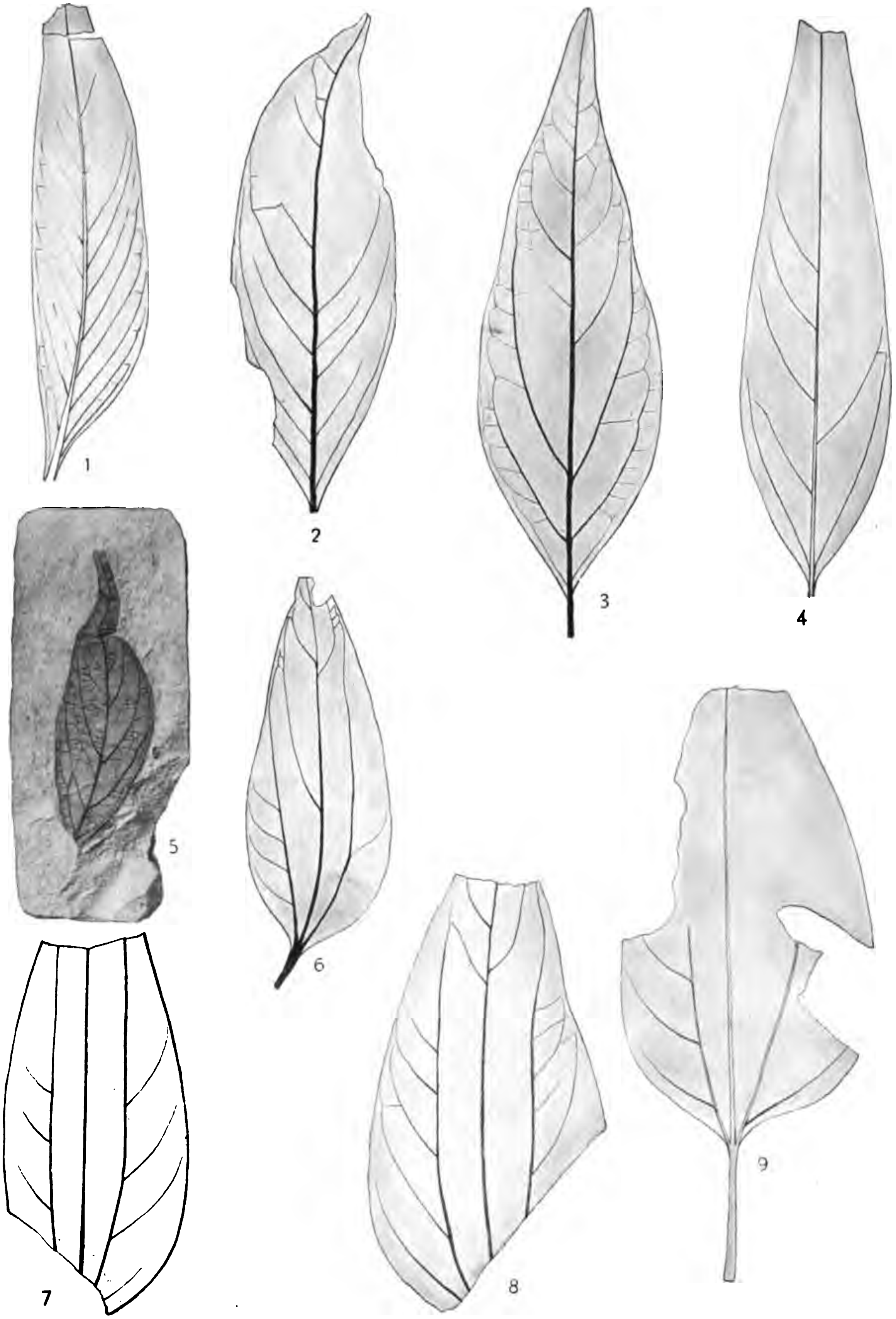
All the fossils are from the Tuscaloosa formation.

PLATE XXI.

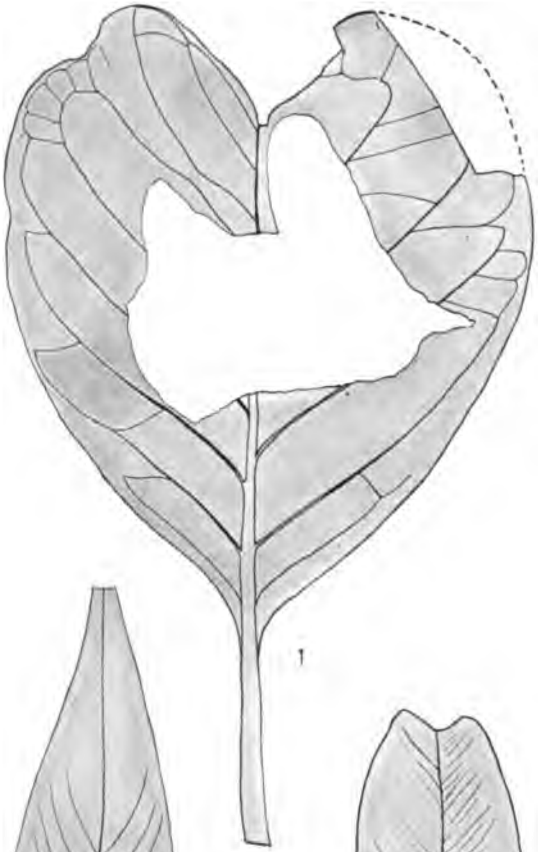
	Page.
FIGURE 1. *Laurophyllum nervillosum* Hollick, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34866)	123
FIGURE 2. *Persea valida* Hollick, from Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34867)	119
FIGURE 3. *Malapoenna cretacea* (Lesquereux) Knowlton, from Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34868)	121
FIGURE 4. *Malapoenna cottondalensis* Berry, from Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34869)	121
FIGURE 5. *Malapoenna falcifolia* (Lesquereux) Knowlton, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34870)	122
FIGURES 6-9. *Cinnamomum newberryi* Berry	118

6. Specimen from Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34871).
7-9. Specimen from Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. Nos. 34872-34874).

All specimens are from the Tuscaloosa formation.



FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.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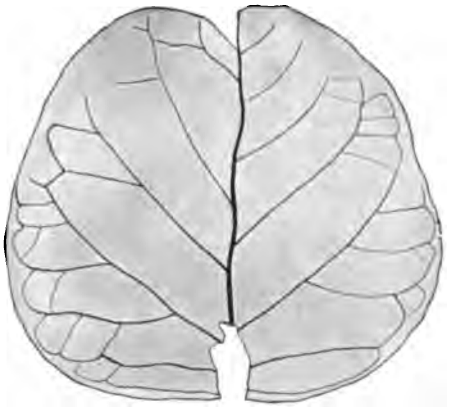
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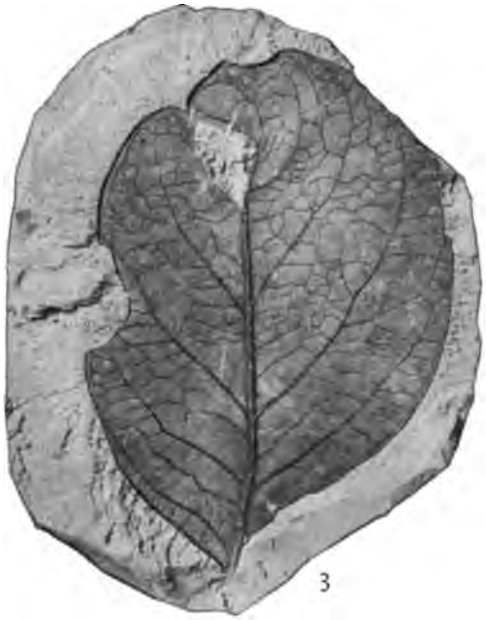
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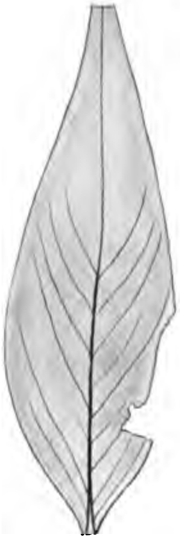
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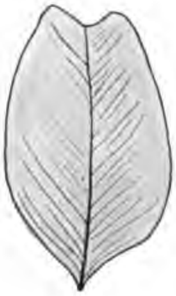
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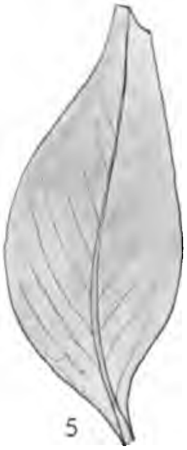
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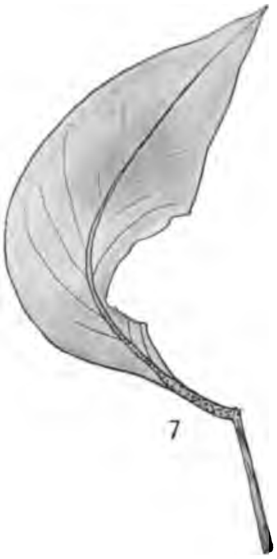
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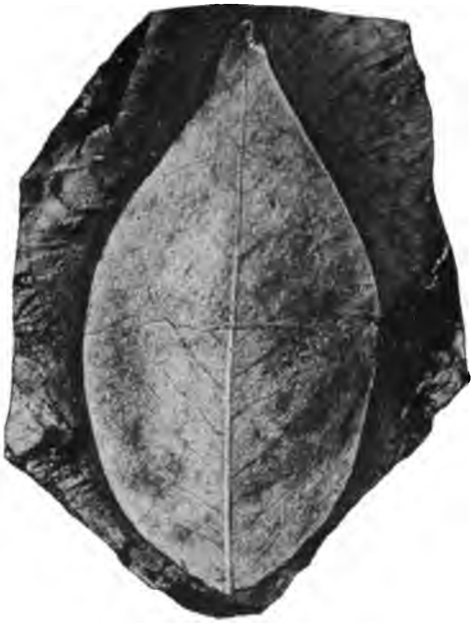

8

FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE XXII.

	Page.
FIGURE 1. *Capparites cynophylloides* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34875)	95
FIGURES 2, 3. *Capparites orbiculatus* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34876, 34877)	96
FIGURES 4, 5. *Inga cretacea* Lesquereux, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34878, 34879)	96
FIGURE 6. *Liriodendropsis simplex* (Newberry) Newberry, from Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34880)	101
FIGURE 7. *Phaseolites formus* Lesquereux, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34881)	101
FIGURE 8. *Cassia vaughani* Berry, from Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34882)	100

All specimens are from the Tuscaloosa formation.

PLATE XXIII.

Page.

FIGURE 1. *Paleocassia laurinea* Lesquereux, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34883) 100

FIGURE 2. *Hymenaea fayettensis* Berry, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34884) 97

FIGURE 3. *Colutea obovata* Berry, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34885) 101

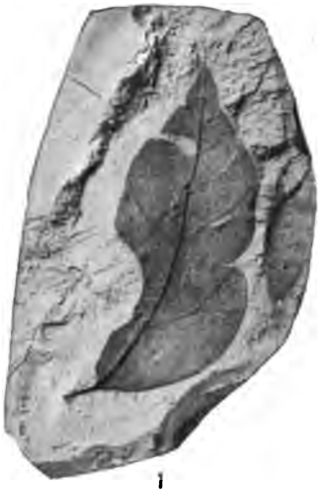
FIGURE 4. *Leguminosites shirleyensis* Berry, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34886) 104

FIGURE 5. *Leguminosites ingaefolia* Berry, from the Tuscaloosa formation at Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34887) 103

FIGURE 6. *Leguminosites tuscaloosensis* Berry, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 3488) 104

FIGURE 7. *Bauhinia ripleyensis* Berry, from the Ripley formation on Cowikee Creek, Barbour County, Ala. (U. S. Nat. Mus. Cat. No. 34889) 100

FIGURE 8. *Bauhinia alabamensis* Berry, from the Eutaw formation at Havana, Hale County, Ala. (U. S. Nat. Mus. Cat. No. 34890) 99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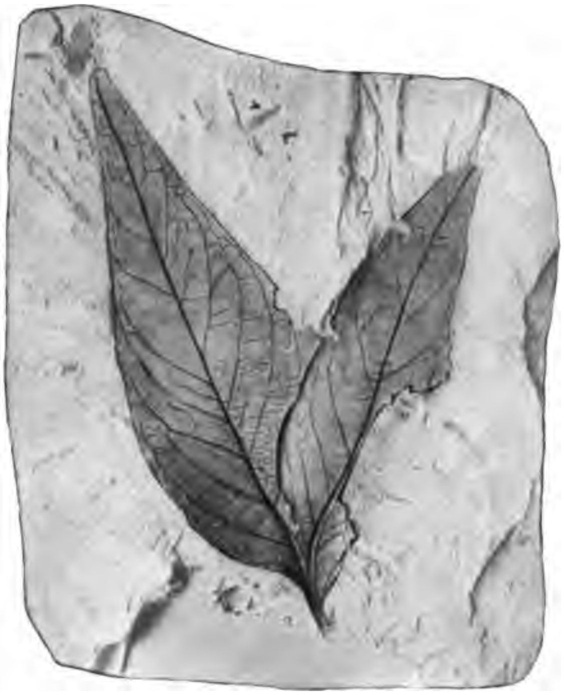
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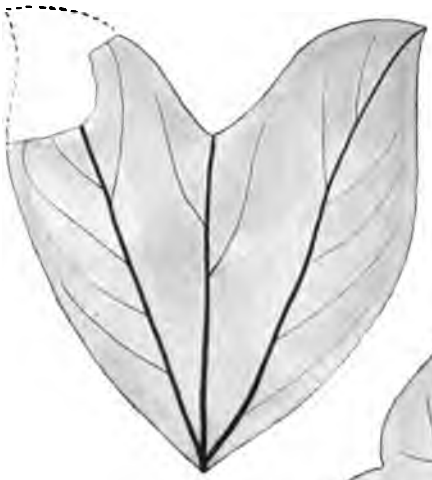
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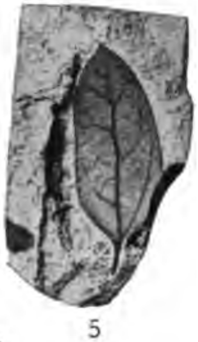
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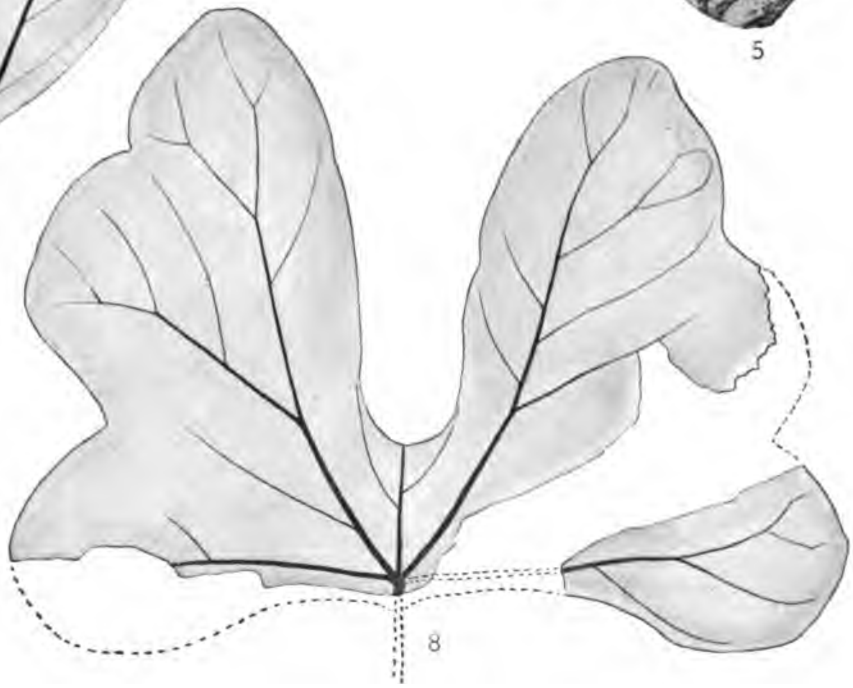
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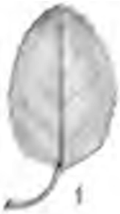
FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.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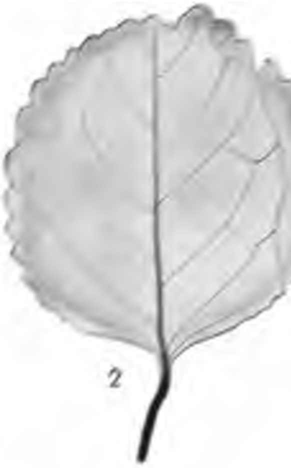
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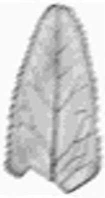
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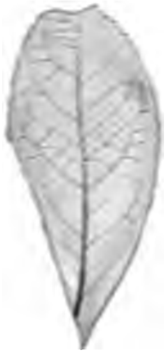
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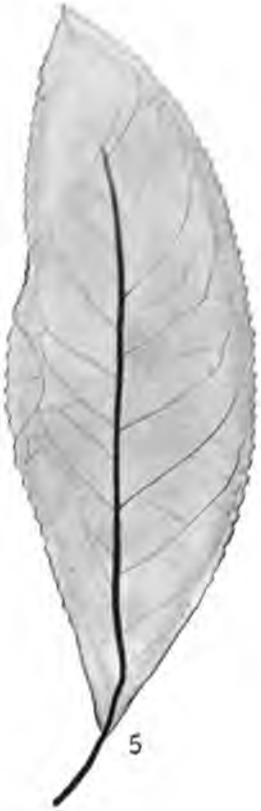
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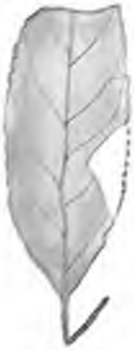
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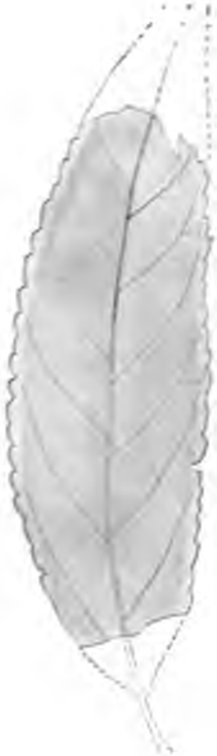
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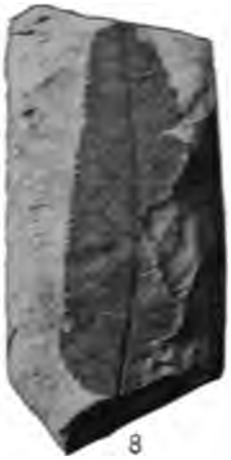
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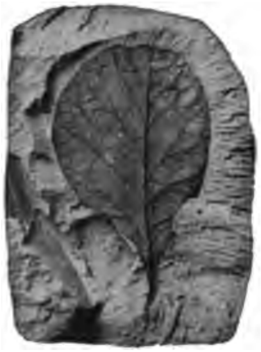
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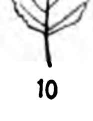
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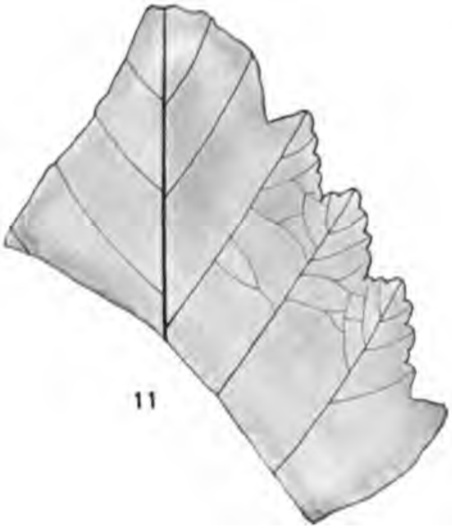
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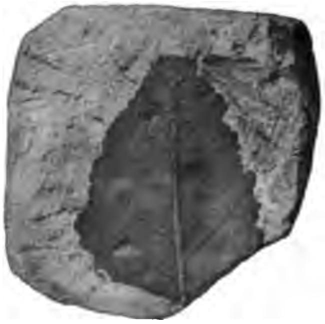
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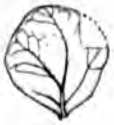

13

FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE XXIV.

	Page.
FIGURES 1, 2. *Celastrophyllum crenatum ellipticum* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34891, 34892)	110
FIGURE 3. *Celastrophyllum shirleyensis* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34893)	107
FIGURE 4. *Celastrophyllum brittonianum* Hollick, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34894)	110
FIGURE 5. *Celastrophyllum grandifolium* Newberry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34895)	108
FIGURES 6, 7. *Celastrophyllum carolinensis* Berry, from gully on Snow place, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. Nos. 34896, 34897)	109
FIGURE 8. *Celastrophyllum shirleyensis* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34898)	107
FIGURE 9. *Celastrophyllum gymindaefolium* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34899)	111
FIGURES 10–12. *Celastrophyllum alabamensis* Berry, from a locality near Centerville, Bibb County, Ala. (U. S. Nat. Mus. Cat. Nos. 34900–34902)	110
FIGURE 13. *Celastrophyllum praecrassipes* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34903)	111

All specimens are from the Tuscaloosa formation.

PLATE XXV.

Paeg.

FIGURES 1, 2. *Rhamnus tenax* Lesquereux, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34904, 34905) 114

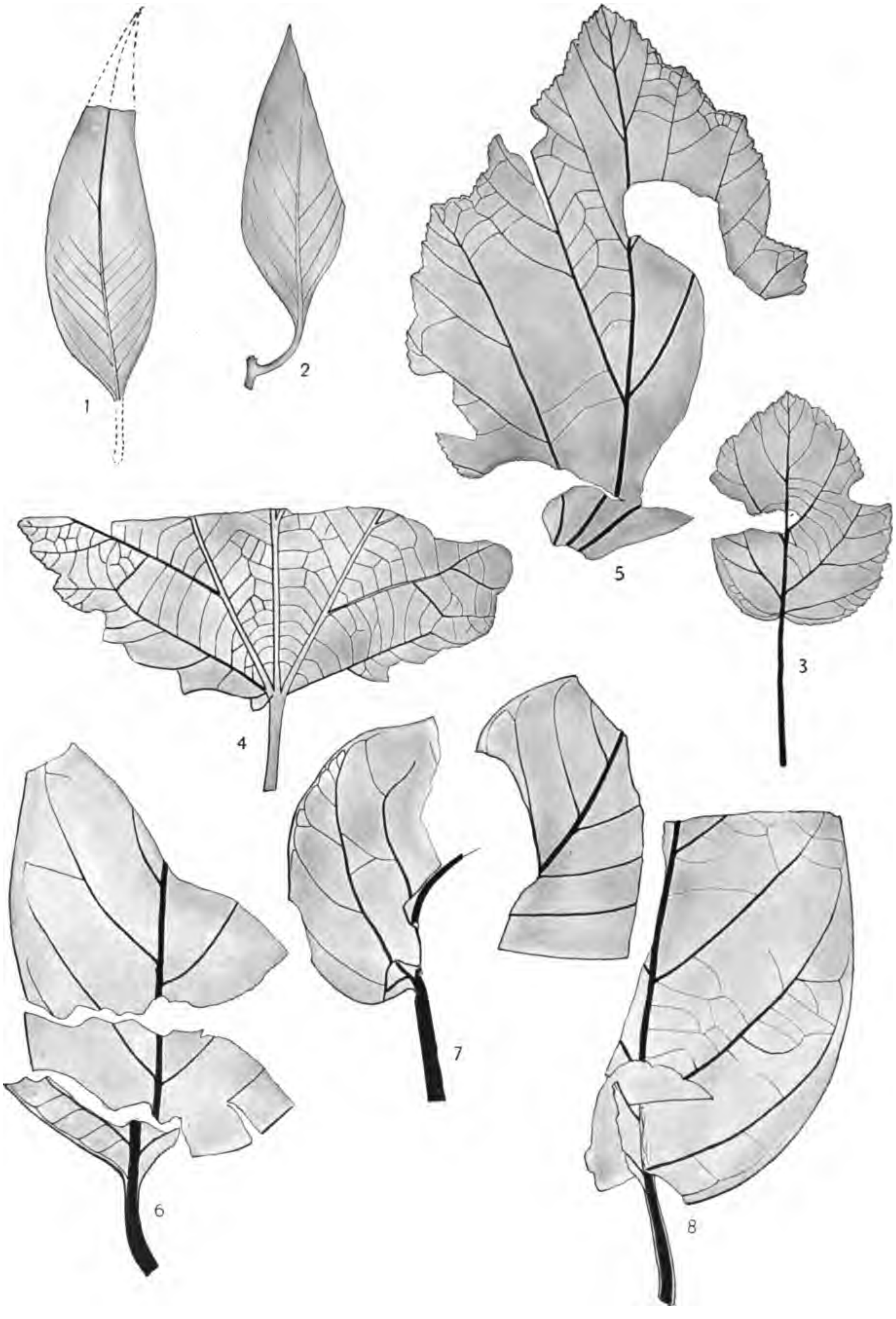
FIGURE 3. *Grewiopsis tuscaloosensis* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34906) 116

FIGURES 4, 5. *Grewiopsis formosa* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34907, 34908) 116

FIGURES 6–8. *Pterospermites carolinensis* Berry 117

6, 7. Specimens from Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34909, 34910).
8. Specimens from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34911).

All specimens are from the Tuscaloosa formation.



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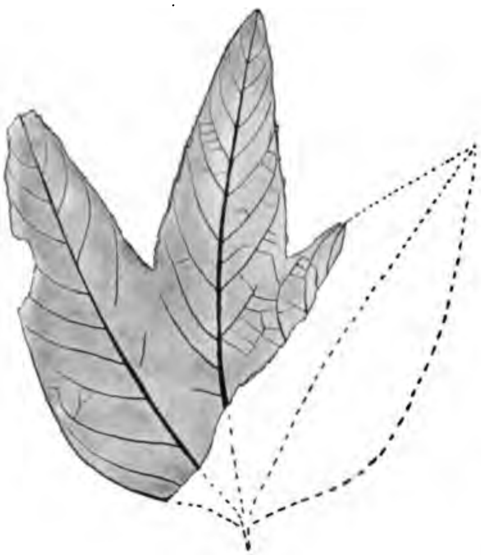

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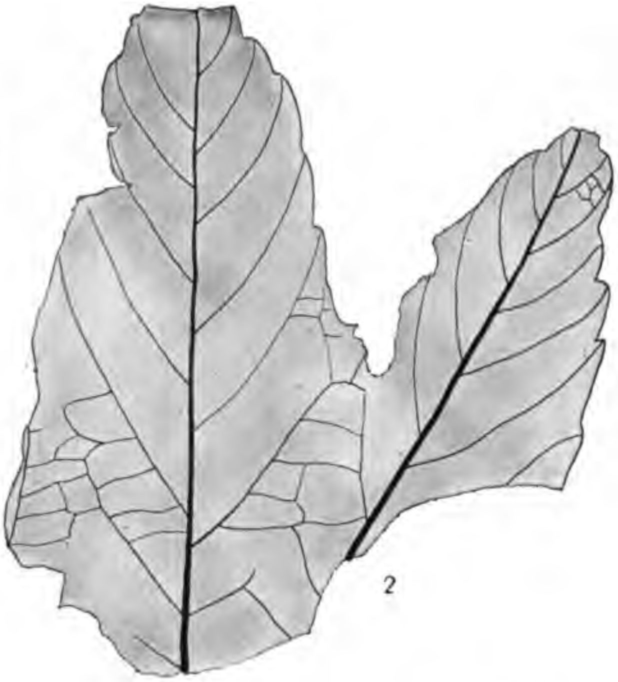

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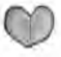

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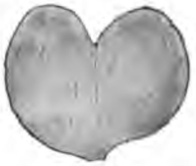

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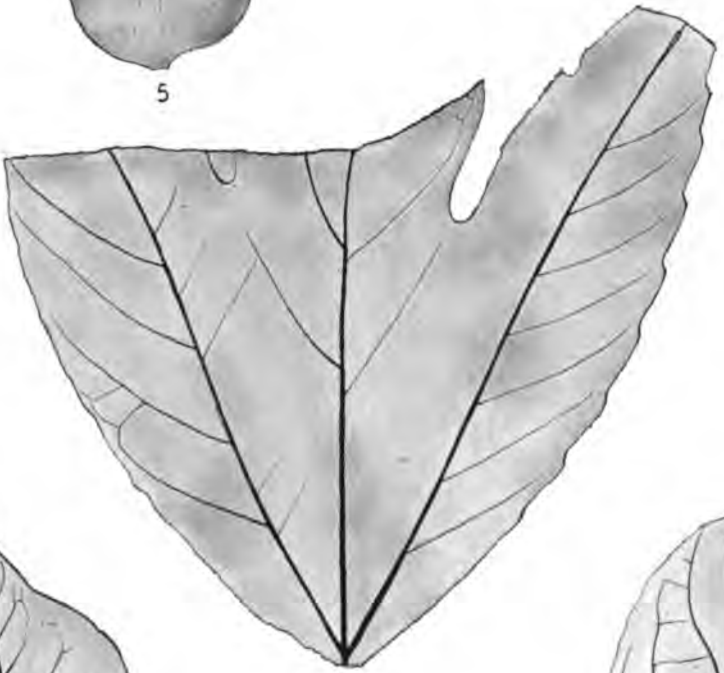

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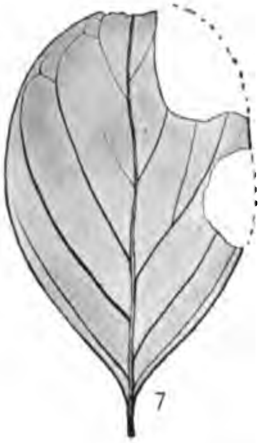

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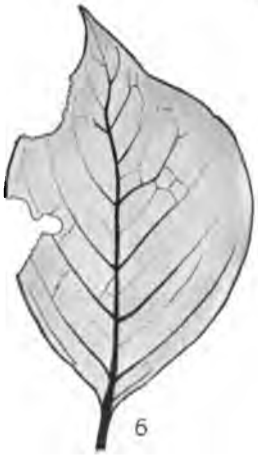

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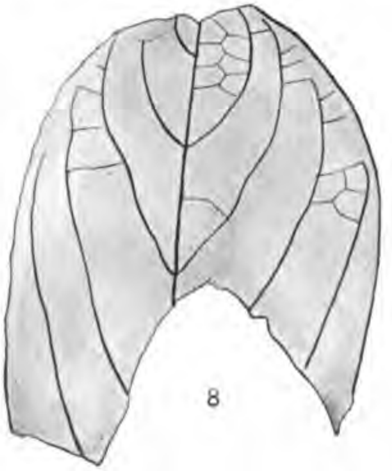


8

FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE XXVI.

Page.

Figures 1–3. *Aralia cottondalensis* Berry, from Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. Nos. 34912–34914) 128

Figures 4, 5. *Panax cretacea* Heer 128

4. Specimen from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34915).
5. Specimen shown in figure 4, × 4.

Figure 6. *Nyssa snowiana* Lesquereux, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34916). 129

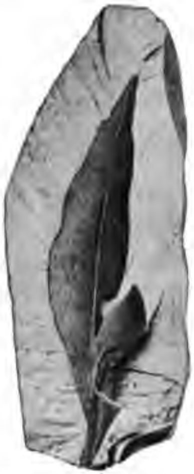
Figures 7, 8. *Cornophyllum obtusatum* Berry, from Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34917; specimen shown in fig. 8 has been destroyed) 129

All specimens are from the Tuscaloosa formation.

PLATE XXVII.

	Page.
FIGURES 1–3. *Sapindus variabilis* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34918–34920)	111
FIGURE 4. *Diospyros rotundifolia* Lesquereux, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34921)	135
FIGURE 5. *Diospyros amboyensis* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34922).	134
FIGURE 6. *Andromeda wardiana* Lesquereux, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34923)	132
FIGURE 7. *Andromeda grandifolia* Berry, a small form from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34924)	131
FIGURE 8. *Dermatophyllites acutus* Heer, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34925)	132

All specimens are from the Tuscaloosa formation.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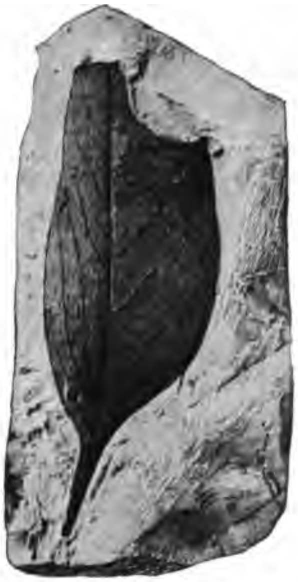
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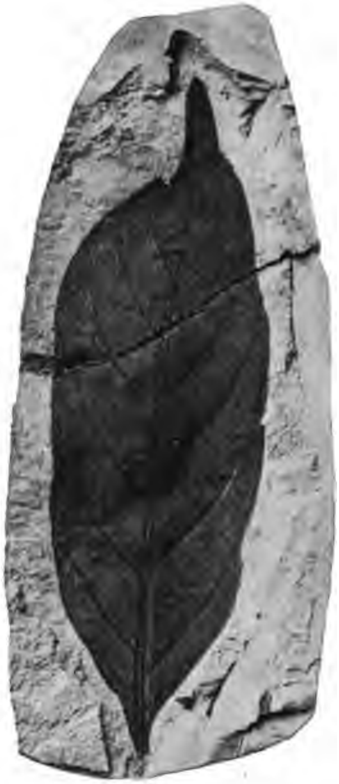
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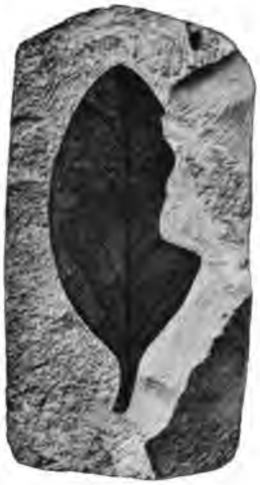
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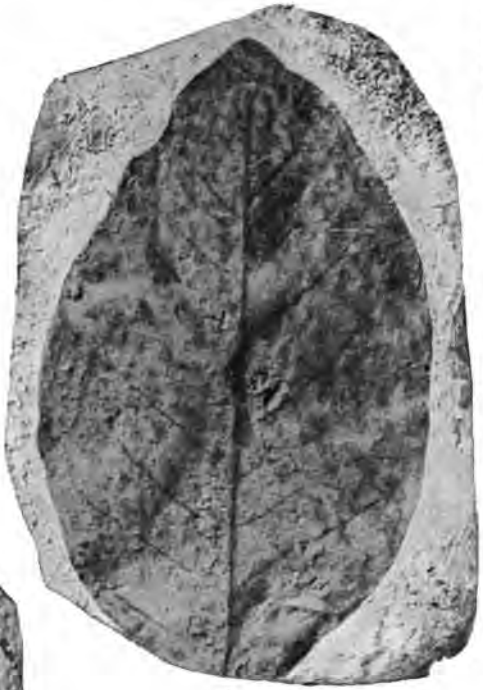
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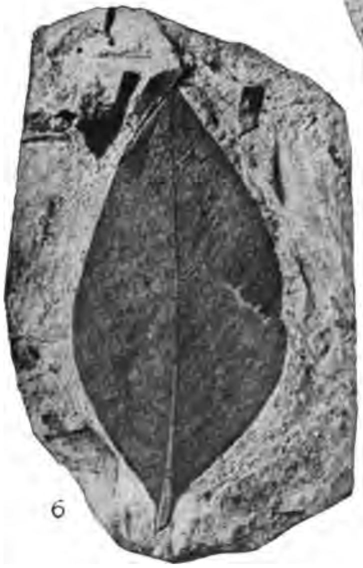
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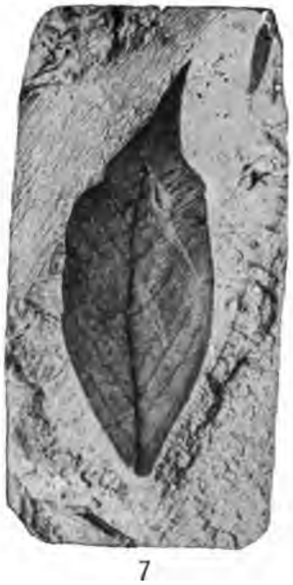
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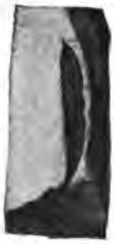
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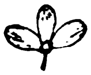
FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.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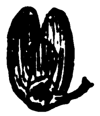
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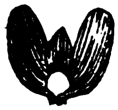
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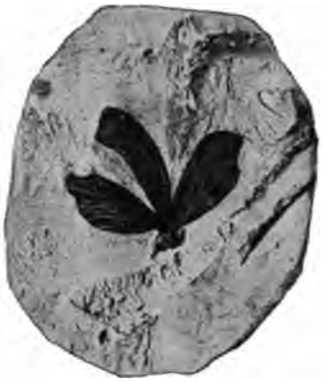
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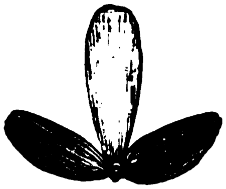
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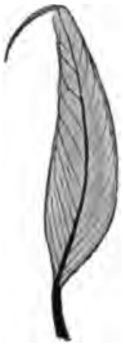
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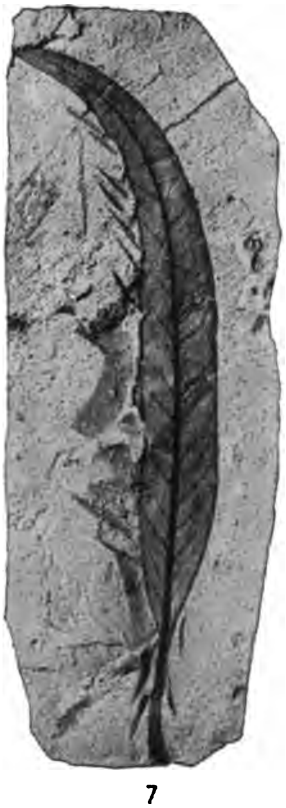
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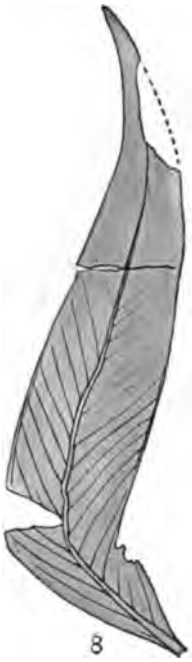
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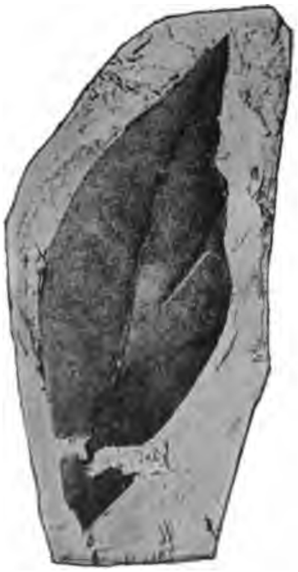
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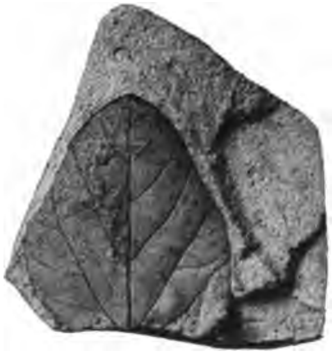
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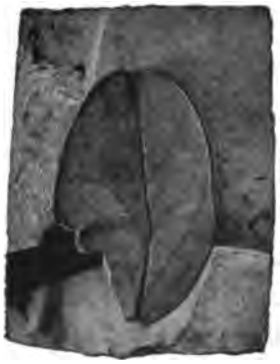

11

FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE XXVIII.

Page.

FIGURES 1–5. *Tricalycites papyraceus* Newberry, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34926–34930) 137

FIGURE 6. *Eugenia tuscaloosensis* Berry, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34931) 125

FIGURE 7. *Myrcia havanensis* Berry, from the Eutaw formation at Havana, Hale County, Ala. (U. S. Nat. Mus. Cat. No. 34932) 125

FIGURE 8. *Eucalyptus geinitzi* (Heer) Heer, from the Tuscaloosa formation in gully on Snow place, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34933) 126

FIGURE 9. *Conocarpites formosus* Berry, from the Tuscaloosa formation at Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34934) 127

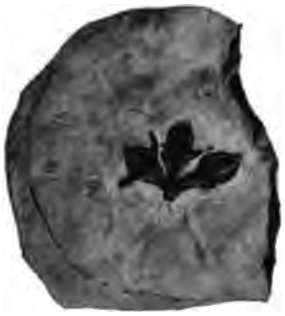
FIGURE 10. *Eorhamnidium cretaceum* Berry, from the Tuscaloosa formation at Cottondale, Ala. (U. S. Nat. Mus. Cat. No. 34935) 113

FIGURE 11. *Sapotacites shirleyensis* Berry, from the Tuscaloosa formation at Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34936) 135

PLATE XXIX.

	Page.
FIGURE 1. *Carpolithus floribundus* Newberry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34937)	131
FIGURE 2. *Phyllites pistiaeformis* Berry, from a locality near Iuka, Tishomingo County, Miss. (U. S. Nat. Mus. Cat. No. 34938)	140
FIGURE 3. *Phyllites shirleyensis* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34939).	139
FIGURES 4–6. *Sapotacites shirleyensis* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34940–34942)	135
FIGURE 7. *Sapotacites ettingshauseni* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34943)	135
FIGURE 8. *Calycites sexpartitus* Berry, from gully on Snow place, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34944)	139

All specimens are from the Tuscaloosa formation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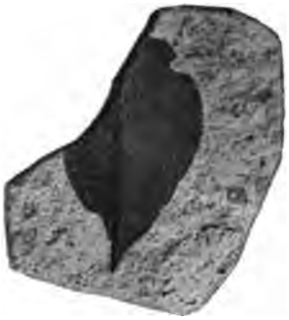
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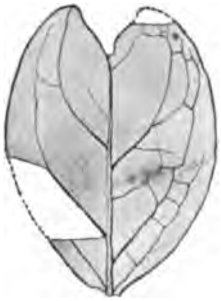
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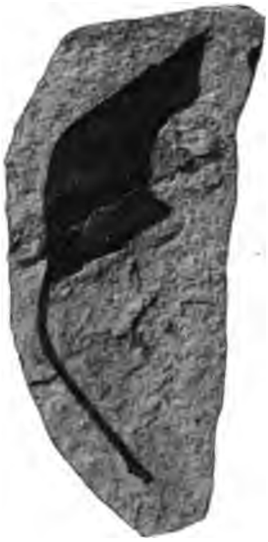
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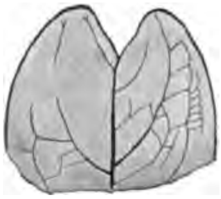
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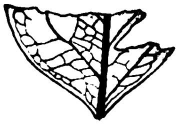
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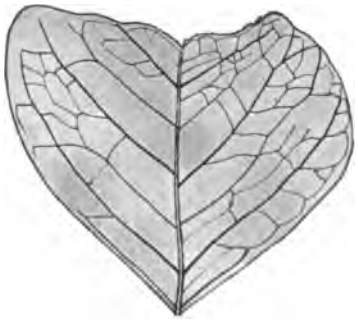
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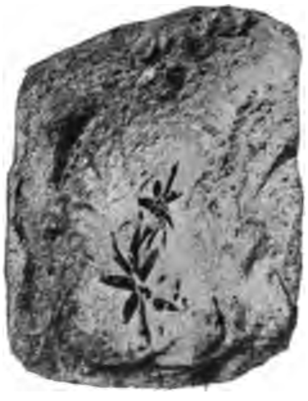
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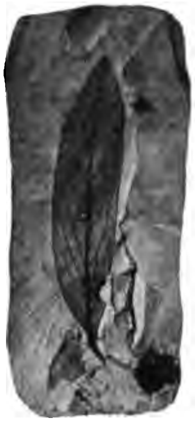
FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.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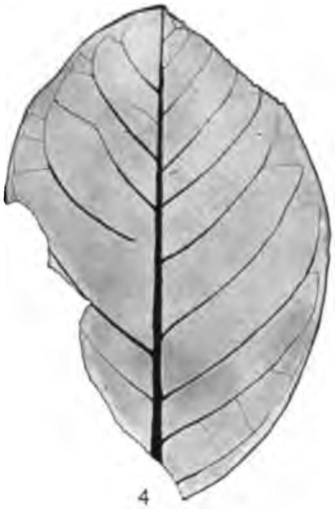
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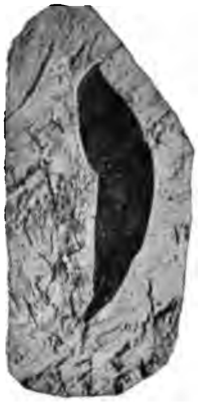
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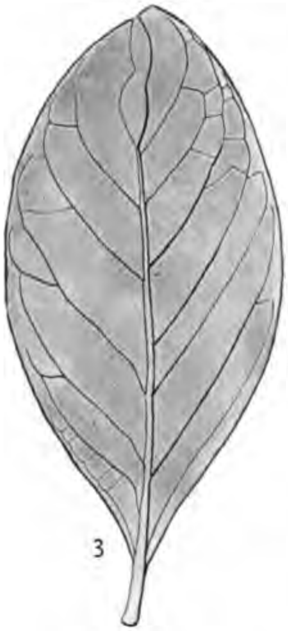
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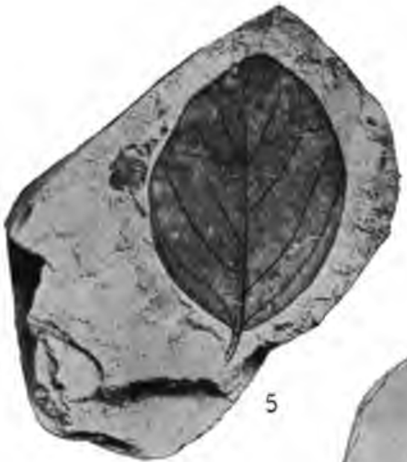
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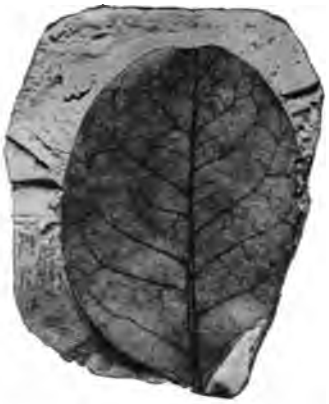
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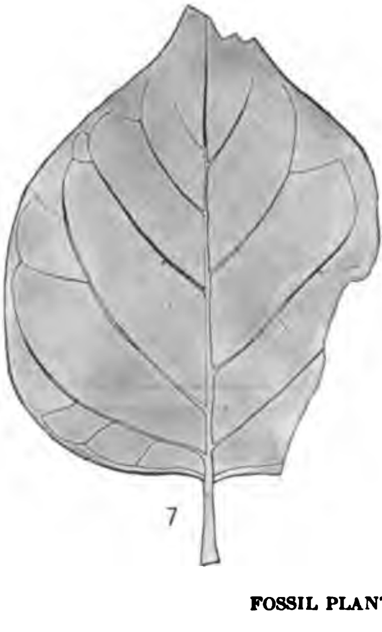
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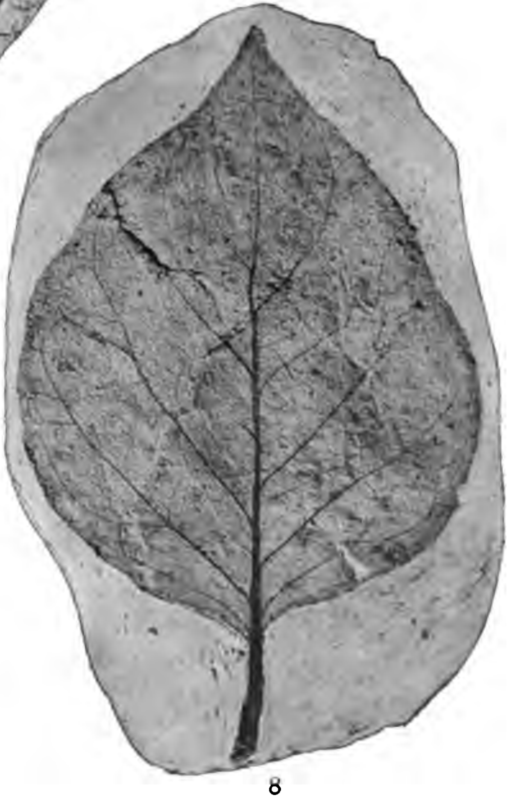

8

FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE XXX.

	Page.
FIGURES 1, 2. *Andromeda novaecaesareae* Hollick, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. Nos. 34945, 34946)	130
FIGURE 3. *Diospyros primaeva* Heer, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34947)	134
FIGURES 4, 5. *Diospyros rotundifolia* Lesquereux	135
4. Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34948).	
5. Cottondale, Tuscaloosa County, Ala. (U. S. Nat. Mus. Cat. No. 34949).	
FIGURE 6. *Sapotacites formosus* Berry, from Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34950).	136
FIGURES 7, 8. *Cordia apiculata* (Hollick) Berry	137
7. Shirleys Mill, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34951).	
8. Glen Allen, Fayette County, Ala. (U. S. Nat. Mus. Cat. No. 34952).	

All specimens are from the Tuscaloosa formation.

PLATE XXXI.

Page.

FIGURE 1. Undeterminable fern pinna (U. S. Nat. Mus. Cat. No. 34953).

FIGURES 2, 3. Undeterminable leaf of *Salix* or *Laurus* (U. S. Nat. Mus. Cat. Nos. 34954, 34955).

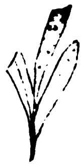
FIGURE 4. Undeterminable leaf of *Sapindus* (U. S. Nat. Mus. Cat. No. 34956).

FIGURES 5, 6. Undeterminable leaf, possibly of *Myrica* (U. S. Nat. Mus. Cat. Nos. 34957, 34958).

FIGURES 7, 8. *Platanus* sp. (U. S. Nat. Mus. Cat. Nos. 34959, 34960).. 85

FIGURE 9. Undeterminable leaf, possibly of *Laurus* (U. S. Nat. Mus. Cat. No. 34961).

All specimens are from the Ripley formation on Cowikee Creek, Barbour County, Ala.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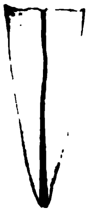
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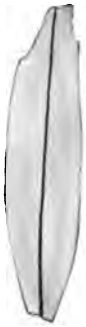
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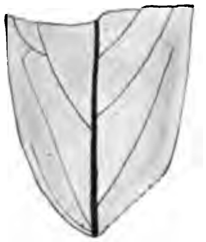
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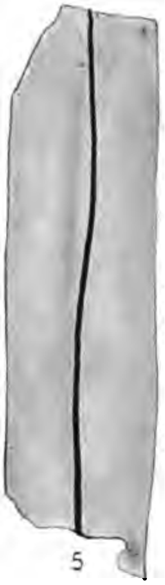
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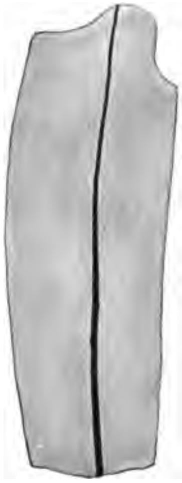
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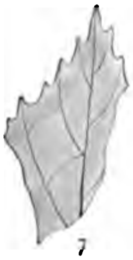
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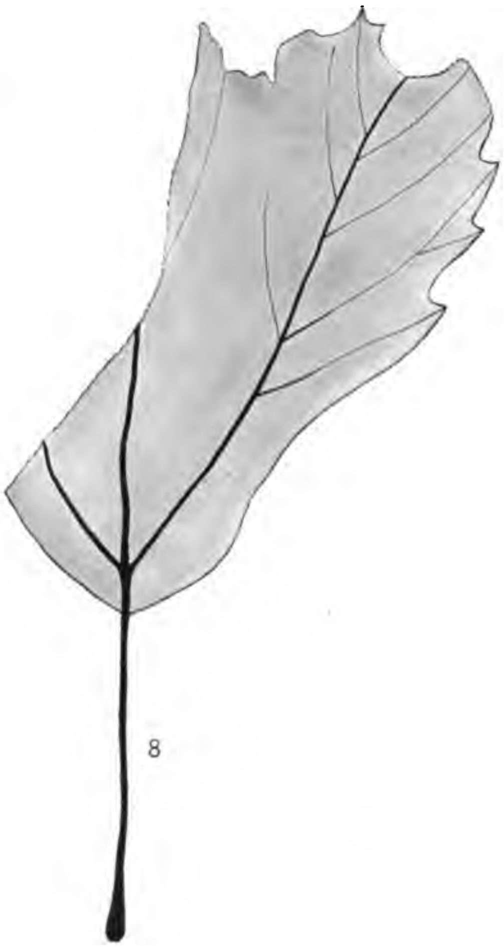
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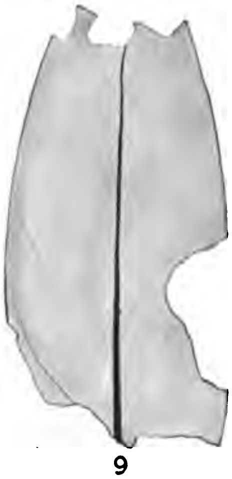
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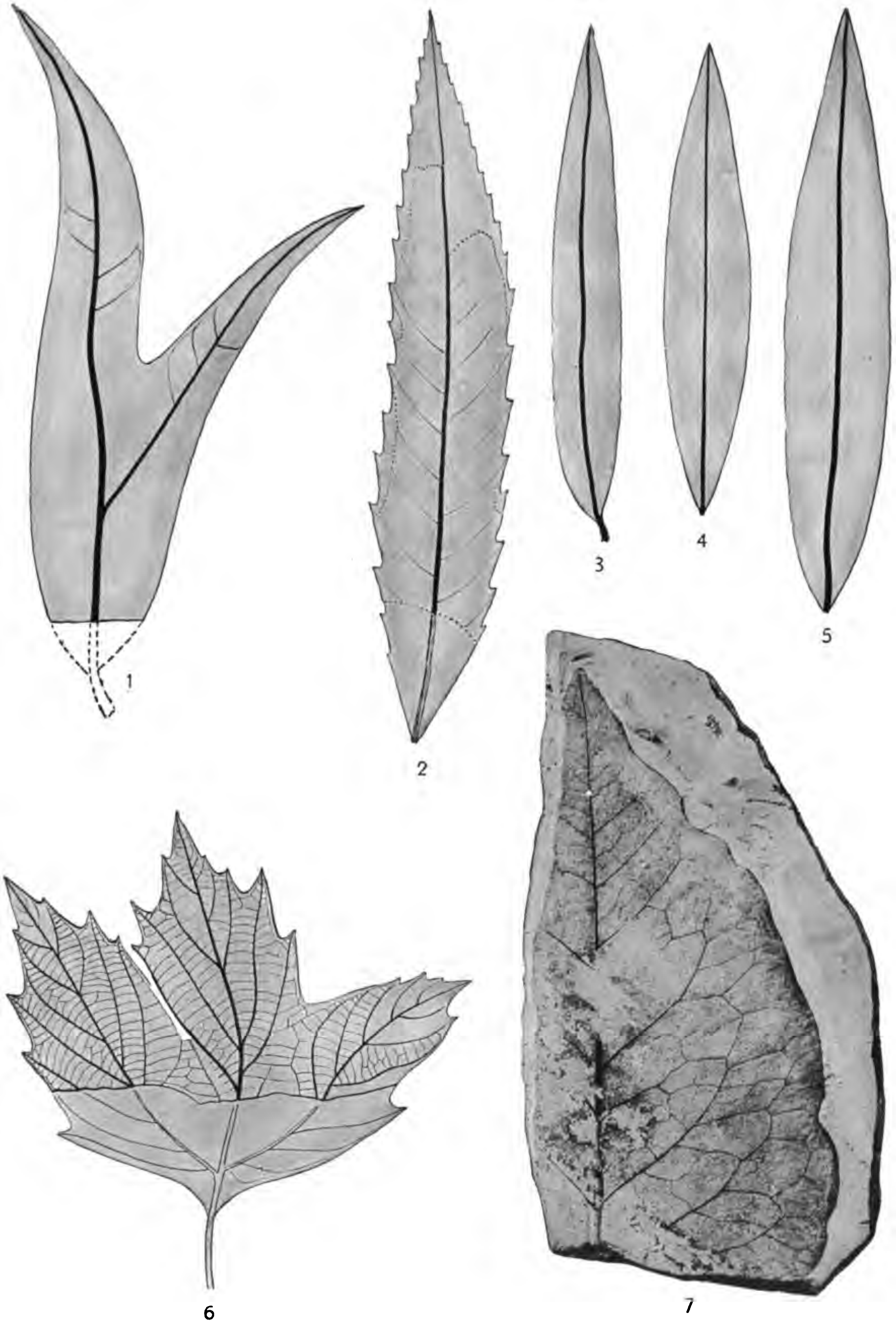
FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.



FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

PLATE XXXII.

Page.

FIGURE 1. *Sterculia snowii tennesseensis* Berry, n. sp., from the McNairy sand member of the Ripley formation near Selmer, McNairy County, Tenn........ 117

FIGURE 2. *Dryophyllum gracile* Debey, from the McNairy sand member of the Ripley formation near Selmer, McNairy County, Tenn........ 75

FIGURES 3-5. *Eugenia* (?) *anceps* Berry, from the McNairy sand member of the Ripley formation near Selmer, McNairy County, Tenn........ 125

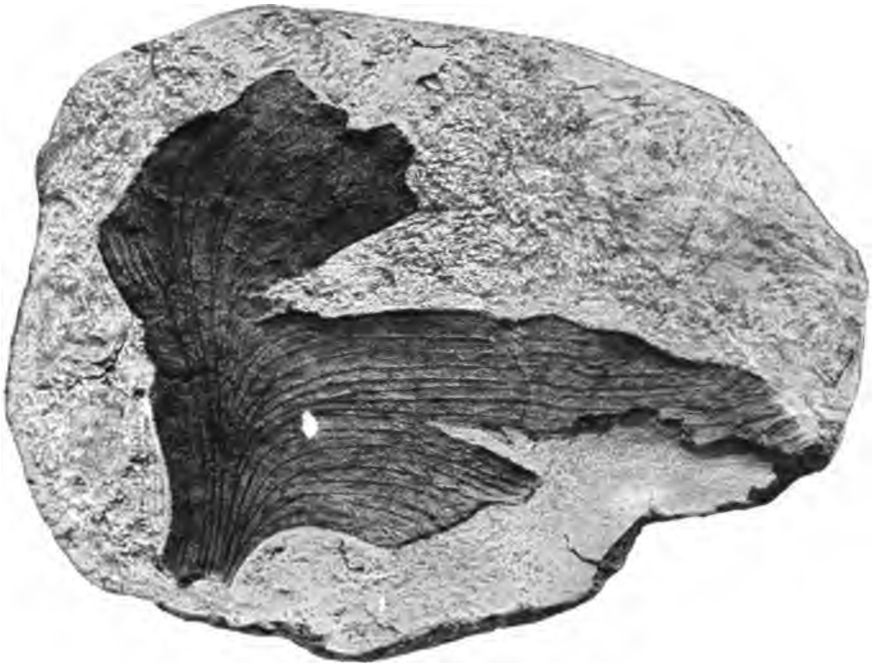
FIGURE 6. *Platanus ripleyensis* Berry, n. sp., from the Ripley formation 6¼ miles north of Eufala, Barbour County, Ala........ 84

FIGURE 7. *Magnolia capellinii*, Heer, from the McNairy sand member of the Ripley formation near Selmer, McNairy County, Tenn........ 89

PLATE XXXIII.

Page.

FIGURES 1-3. *Phyllites asplenioides* Berry, n. sp., from the Coffee sand member of the Eutaw formation at Coffee Bluff, Hardin, Hardin County, Tenn. 140



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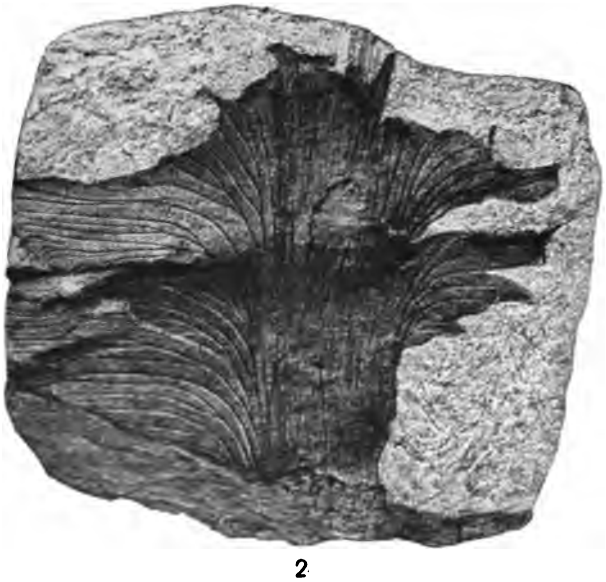

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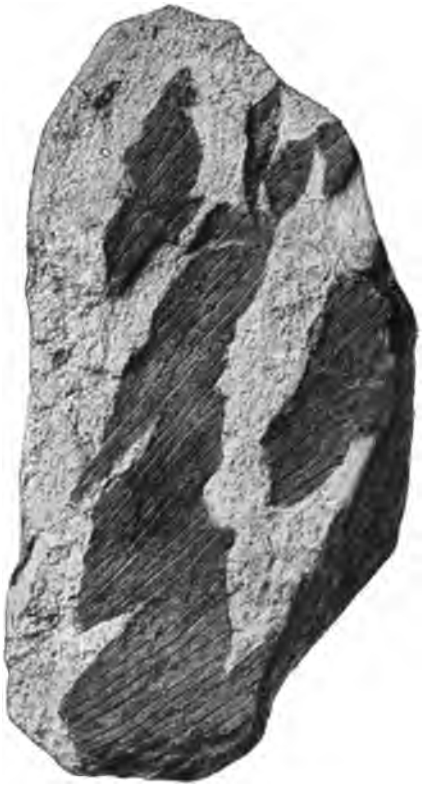

3

FOSSIL PLANTS FROM THE UPPER CRETACEOUS FORMATIONS.

INDEX.

Names in *italic* are synonyms; figures in black face indicate descriptions; figures in *italic* indicate illustrations.

A. Page.

- Abietites Hissinger, 64
  - foliosus (Fontaine) Berry, **64**
- Acerates Nilsson, 136–137
  - amboyensis Berry, **136–137**
  - *sp.* Hollick, 136
- Amber, occurrence of, 13, 14
- Andromeda Linné, 130–132
  - cretacea Lesquereux (?), **132**
  - grandifolia Berry, **131**, *166*
  - *latifolia* Newberry, 85, 131
  - novaecaesareae Hollick, **130**, *169*
  - parlatorii Heer, **131–132**
  - wardiana Lesquereux, **132**, *166*
- Androvettia Hollick and Jeffrey, 62–64
  - carolinensis Berry, **62–64**, *146*
  - elegans, **64**
  - statenensis, 63
- Anemia, 53
- *Anemia stricta* Newberry, 54
- Angiospermae, 70–141
- Aralia Linné, 128
  - cottondalensis Berry, n. sp, **128**, *165*
  - eutawensis Berry, **128**
  - looziana Saporta and Marion, 128
  - wellingtoniana Lesquereux, 84
  - *wellingtoniana* Ward, 128
- Araliaceae, 128
- Araucaria Jussieu, 61–62
  - bidwilli, 62
  - bladenensis Berry, **61–62**, *148*, *149*
  - jeffreyi Berry, **62**
  - *reichenbachi* (Geinitz) Heer, 64
  - toucasi, 62
- Araucarites ovatus, 62
  - *reichenbachi* Geinitz, 64
- Arecales, 72
- Arthrotaxopsis, 60
  - *expansa* Fontaine, 66
- Asclepiadaceae, 136–137
- Aspidiophyllum trilobatum Lesquereux, 95
- Asplenites roesserti, 51
- Asplenium Linné, 53–54
  - dicksonianum Heer, **53–54**

B.

- Bambusium latifolium, 71
- Bauhinia Linné, 97–100
  - alabamensis Berry, **99–100**, *162*
  - cretacea Newberry, **97–98**, 99
  - gigantea Newberry, 100
  - marylandica Berry, **98–99**, 100
  - ripleyensis Berry, **100**, *162*
- Benton County, Tenn., fossil plants collected from, 38
- Benzoin masoni (Lesquereux) Knowlton, 83
  - venustum (Lesquereux) Knowlton, 83
- Bingen flora, relation of the Tuscaloosa flora to, 41
- Black Warrior River, fossil plants collected on, 17–18, 19, 20, 21–22
- Borraginaceae, 137
- Boundaries of the region, 7
- Brachyphyllum Brongniart, 59–60
  - macrocarpum formosum Berry, **59–60**, *144*
- Broken Arrow Bend, Ga., section measured and fossil plants collected at, 32
- Bryophyta, 49
- Buena Vista, Ga., section measured and fossil plants collected east of, 38
- Bumelia, 136
- Byron, Ga., fossil plants collected near, 38

C. Page.

- Caesalpiniaceae, 97–101
- Callitris Ventenat, 68, 69
- Calycites alatus Hollick, 138
  - obovatus Hollick, 138
  - sexpartitus Berry, n. sp, **139**, *168*
- Camden, Tenn., Ripley formation northwest of, plate showing, 32
- Capparidaceae, 95–96
- Capparis cynophallophora Linné, 96
- Capparites Berry, n. gen, 95–96
  - cynophylloides Berry, n. sp, **95–96**, *161*
  - orbiculatus Berry, n. sp, **96**, *161*
- Carpolithus floribundus Newberry, **139**, *168*
  - pruniformis Newberry, 49–50
  - tuscaloosensis Berry, n. sp, **139**
- Cassia Linné, 100–101
  - melanophylla Velenovsky, 81
  - vaughani Berry, n. sp, **100–101**, *161*
- *Caulerpites fastigiatus* Sternberg, 67
- Celastraceae, 106–111
- Celastrophyllum Goeppert, 106–111
  - variation of, 39–40
  - acutidens Fontaine, 107
  - alabamensis Berry, n. sp, **110**, *163*
  - albaedomus Ward, 107, 111
  - *angustifolium* Newberry, 106
  - brittonianum Hollick, 107, **110–111**, *163*
  - carolinensis Berry, **109**, *163*
  - crenatum Heer, 108, **109–110**
    - ellipticum Berry, n. var, **110**, *163*
  - decurrens Lesquereux, **106–107**
  - grandifolium Newberry, **108–109**, *163*
  - gymindaefolium Berry, n. sp, **111**, *163*
  - lanceolatum, 108
  - latifolium Fontaine, 111
  - minus Hollick, 111
  - newberryanum Hollick, **106**
  - praecrassipes Berry, n. sp, **111**, *163*
  - shirleyensis Berry, n. sp, **107**, *163*
  - spatulatum Newberry, 111
  - undulatum Newberry, **107**
- Celastrus arctica, 87
- Cephalotaxospermum Berry, 56–57
  - carolinianum Berry, **56–57**
- Chimney Bluff, Ga., section measured and fossil plants collected at, 32–33
- Cinnamomum Blume, 118–119
  - heerii Lesquereux (?), 118, 122
  - *intermedium* Newberry, 118
  - newberryi Berry, **118**, *160*
  - *sezannense* Heer, 118
  - sp, **118–119**
- Cissites Heer, 115
  - crispus Velenovsky, **115**
  - formosus Heer, **115**
  - insignis, 115
  - newberryi, 115
- Citrophyllum Berry, 104–105
  - aligerum (Lesquereux) Berry, **104–105**
- Cladophlebis Brongniart, 51–52
  - alabamensis Berry, n. sp, **51–52**, *144*
  - albertsii, 51
  - browniana, 51, 52
  - parva, 51
  - ungeri, 51
  - whitbyensis, 51
- Cocculus De Candolle, 93–94
  - cinnamomeus Velenovsky (?), **93**, 94, *156*
  - polycarpaefolius Berry, n. sp, **94**, *156*
  - problematicus Berry, n. sp, **94**, *156*

Page.
Coffee Bluff, Tenn., section measured and fossil plants collected at. 33–35
Colutea Linné 101
  obovata Berry **101**, *162*
  protogaea Heer 136
Collections, localities of 14–22, 32–35, 37–39
Combretaceae 127–128
Comptonia peregrina (Linné) Coulter 74
  vindobonensis (Ettingshausen) Berry 74
Comptonites antiquus Unger 74
Coniferales 56–70
Conocarpites Berry, n. gen **127–128**
  formosus Berry, n. sp **127–128**, *167*
Conocarpus erectus 127
Cordaites 70
Cordia Linné 137
  apiculata (Hollick) Berry, n. comb **137**, *169*
Cornaceae 129–130
Cornophyllum Newberry 129–130
  obtusatum Berry, n. sp **129–130**, *165*
  vetustum Newberry **129**
Cornus 129
  platyphylloides Lesquereux 114
Cottondale, Ala., section measured and fossil plants collected at. 18–19
Cowikee Creek, Ala., fossil plants on 38
Cretaceous, Lower, sediments, distribution of 7
  Upper, sediments, distribution of 7–8
    sediments, fossil plants from, plates showing 144–172
Crotonophyllum Velenovsky 105–106
  panduraeformis Berry **105–106**
Cunninghamia elegans Corda 58
Cunninghamites Presl 58
  elegans (Corda) Endlicher **58**
  squamosus Heer 61
Cupressinoxylon Goeppert 70
  sp **70**
Cyatheaceae 54
Cycadales (?) 55–56
Cycadinocarpus Schimper 56
  circularis Newberry **56**
Cyperacites Schimper 71
  sp. Hollick 71
Cyperites? Hollick 71
Cypress, Tenn., fossils collected near 38

D.

Dammara Lamarck 58–59
  borealis Heer **58–59**
  microlepis Hollick 60
  minor Hollick 60
Dermatophyllites Goeppert 132
  acutus Heer **132**, *166*
Dewalquea Saporta and Marion 86–88
  groenlandica Heer 76
  smithi Berry **86–88**, *153*, *155*
Dicksonia Presl 54
  borealis Heer 54
  groenlandica Heer **54**, 66
Dicotyledonae 72–141
Dicotyledons, Tuscaloosan, origin of 25
Diospyros Linné 134–135
  amboyensis Berry **134–135**, *166*
  primaeva Heer **134**, *169*
  rotundifolia Lesquereux **135**, *166*, *169*
  rotundifolia Lesquereux 104, 133
Doryanthites Berry 70–71
  cretacea Berry **70–71**, *152*
Dryandra cretacea Velenovsky 74
Dryophyllum Debey 75
  gracile Debey **75**, *171*
Dryopteris 52, 53
Dryopterites Berry 52–53
  kennerleyi 53
  oerstedi 53
  stephensoni Berry **52–53**

E.

Ebenaceae 134–135
Ebenales 134–136
Ecologic conditions, indications of 26–30, 35–36
Eolirion 71
Eorhamnidium Berry, n. gen **113**
  cretaceum Berry, n. sp **113–114**, *167*
  platyphylloides (Lesquereux) Berry, n. comb **114**
Equisetales 49–50
Equisetum Linné 49–50
Equisetum? sp. Berry **49–50**
Ericaceae? 130–133
Ericales? 130–133
Eucallitris 68, 69
Eucalyptus L'Héritier 126–127
  angusta Velenovsky **127**
  angustifolia Newberry 126
Eucalyptus? attenuata Newberry 80
  attenuata Ward 125
  geinitzi (Heer) Heer **126–127**, *167*
  latifolia Hollick **126**
Eugeinitzia 65
Eugenia Linné 125
  anceps Berry **125**, *171*
  primaeva Lesquereux 125
  tuscaloosensis Berry, n. sp **125**, *167*
Euphorbiaceae 105–106
Euphorbiophyllum antiquum Saporta and Marion 85
European Upper Cretaceous floras, relation of the Tuscaloosa flora to 41
Eutaw formation, distribution of 7–8, 31
  flora of, composition of 35
    correlation of 41–42
    distribution of species of 43–48
    ecologic conditions indicated by 35–36
  materials of 31
  plate showing 32
  sections of 32–35
  small representation of 7
  stratigraphic relations of 31–32
  studies on 30–31

F.

Fagaceae 75
Fagales 75
Ficus Linné 78–83
  alabamensis Berry, n. sp **82**, *153*
  aligera Lesquereux 104
  atavina Heer 73
  atavina Heer (?) 78
  beckwithii Lesquereux 78
  crassipes (Heer) Heer **79**
  daphnogenoides (Heer) Berry 79, 80, 96, *152*
  fontainii Berry, n. sp **82–83**, *150*
  georgiana Berry **79**
  inaequalis Lesquereux **80–81**, *151*
  krausiana Heer **78–79**
  ovata Newberry 79
  ovatifolia Berry **79**, 82
  proteoides Lesquereux 80
  shirleyensis Berry, n. sp **81**, *152*
  suspecta Velenovsky 78
  tiliaefolia (Alexander Braun) Heer 83
  woolsoni Hollick 79, **81–82**, *151*
Filicales 51–55
Frenela 68, 69
Frenelites reichii Ettingshausen 69
Frenelopsis 68
Fungi 49

G.

Geinitzia Endlicher 61
  formosa Heer **61**
  sp. Newberry 61
Gentianales 136–137
Geraniales 104–106
Gleichenia Smith 51, 54–55
  delicatula Heer **54–55**
  micromera Heer 54
Gleicheniaceae 54–55
Glen Allen, Ala., section measured and fossil plants collected at. 14–16
  Tuscaloosa formation near, plate showing 14
Glyptostrobus gracillimus Lesquereux 69

Page.

- Graminales ... 71–72
- Grewiopsis Saporta ... 116–117
  - formosa Berry, n. sp ... **116**, *164*
  - tuscaloosensis Berry, n. sp ... **116–117**, *164*
- Gyminda grisebachii ... 111
- Gymnospermae ... 55–70
- Gypsum, occurrence of ... 13, 26

H.

- Halymenites major Lesquereux ... 140
- Havana, Ala., Eutaw formation east of, plate showing ... 32
  - section measured and fossil plants collected near ... 33
- Hedera primordialis Saporta ... 82
- Hepaticae ... 49
- Hymenaea Linné ... 97
  - dakotana Lesquereux ... 97
  - fayettensis Berry, n. sp ... **97**, *162*

I.

- Ilex Linné ... 106
  - masoni Lesquereux ... **106**
- Ilicaceae ... 106
- Inga Willdenow ... 96–97
  - cretacea Lesquereux ... **96–97**, 103, *161*
- Iuka, Miss., fossil plants collected at ... 14
  - Tuscaloosa formation near ... 16

J.

- Juglandaceae ... 73
- Juglandales ... 73
- Juglans Linné ... 73
  - arctica Heer ... **73**
  - crassipes Heer ... 73
- Jungermanniales ... 49
- Jungermannites Goeppert ... 49
  - cretaceus Berry, n. sp ... **49**, *144*
  - vetustior ... 49

K.

- Kalmia Linné (?) ... 132–133
  - brittoniana Hollick ... **132–133**
- Krannera ... 71
- Krugiodendron ferreum ... 113, 114

L.

- *Laricopsis longifolia* Fontaine ... 64
- Lauraceae ... 118–125
- Laurophyllum Goeppert ... 123–125
  - angustifolium Newberry ... 124
  - elegans Hollick ... **124–125**
  - lanceolatum Newberry ... 124
  - nervillosum Hollick ... **123–124**, *160*
- Laurus Linné ... 123
  - plutonia ... **123**
- Leguminosae ... 103–104
  - ingaefolia Berry, n. sp ... **103**, *162*
  - omphalobioides Lesquereux ... **103**
  - shirleyensis Berry, n. sp ... **104**, *162*
  - tuscaloosensis Berry, n. sp ... **104**, *162*
- Leguminosites Bowerbank ... 103–104
- *Leptostrobus foliosus* Fontaine ... 64
- *Leucothoe parlatorii* (Heer) Schimper ... 131
- Lignite, occurrence of ... 13, 26, 30
- Liliales ... 70–71
- Liriodendron Linné ... 92–93
  - meekii Heer ... **92–93**, *159*
    - *genuina* Heer ... 92, 93
    - *primaeva* Heer ... 92, 93
  - *primaevum* Newberry ... 92, 93
  - *simplex* Newberry ... 101, 102
  - succedens Dawson ... 105
- Liriodendropsis Newberry ... 101–103
  - angustifolia Newberry ... **102–103**
  - constricta (Ward) Hollick ... **103**
  - simplex (Newberry) Newberry ... **101–102**, 103, *161*
    - *constricta* Ward ... 103
  - spectabilis Hollick ... 102
- *Litsea cretacea* Lesquereux ... 121
  - *falcifolia* Lesquereux ... 122
- Localities of the fossils collected ... 7
- Lycopodiales ... 50–51
- Lycopodites Brongniart ... 50–51
  - tuscaloosensis Berry, n. sp ... **50–51**, *144*
- Lycopodium Linné ... 50
  - cretaceum Berry ? ... **50**

M.

- McBrides Ford, Ga., section measured and fossil plants collected at ... 32
- Magnolia Linné ... 88–92
  - *alternans* Heer ... 91
  - *auriculata* ... 88, 92
  - boulayana Lesquereux ... **90–91**, *157*
  - capellinii Heer ... **89**, 90, *157*, *171*
  - *glaucoides* Hollick ... 90
  - hollicki Berry ... **92**
  - inglefieldi Heer ... 91
  - lacoeana Lesquereux ... **91**, *156*
  - *longifolia* Hollick ... 89
  - longipes Hollick ... 90, **91**
  - newberryi Berry ... **89–90**, *159*
  - obtusata Heer ... **90**, *156*
  - speciosa Heer ... **88–89**, 91, 92, *157*
  - vaningeni ... 90
  - woodbridgensis ... 90, 91
- Magnoliaceae ... 88–93
- Magothy flora, relation of the Tuscaloosa flora to ... 40–41
- Malapoenna Nees ... 121–123
  - cottondalensis Berry, n. sp ... **121**, *160*
  - cretacea (Lesquereux) Knowlton ... **121–122**, *160*
  - falcifolia (Lesquereux) Knowlton ... **122**, *160*
  - horrellensis Berry ... **122–123**
- Malvales ... 116–118
- Manihotites Berry ... 106
  - georgiana Berry ... **106**
- Map of eastern Gulf region, showing distribution of Upper Cretaceous deposits ... 8
- Marattia Swartz (?) ... 55
  - cretacea Velenovsky (?) ... **55**
- Marattiaceae (?) ... 55
- Menispermaceae ... 93–95
- Menispermites Lesquereux ... 94–95
  - borealis Heer ... 94
  - integrifolius Berry, n. sp ... **94–95**, *159*
  - trilobatus Berry, n. sp ... **95**, *156*
  - variabilis Berry ... **95**
- Microzamia gibba Corda ... 61
- Mimosaceae ... 96–97
- Mimusops ... 136
  - ballotaevides ... 73
- Monocotyledonae ... 70–72
- Monocotyledons, Tuscaloosan, scarcity of ... 24
- Moraceae ... 78–83
- Moriconia ... 63
- Myrcia De Candolle ... 125–126
  - havanensis Berry ... **125–126**, *150*, *167*
- Myrica De Candolle ... 73–75
  - dakotensis minima Berry, n. var ... **74**, *152*
  - emarginata Heer ... **73**, *152*
  - longa (Heer) Heer ... 74
  - ripleyensis Berry ... **74–75**, *150*
  - zenkeri Heer ... 107
- Myricaceae ... 73–75
- Myricales ... 73–75
- Myrsinaceae ... 133–134
- Myrsine Linné ... 133–134
  - borealis Heer ... **133–134**, 135
  - *elongata* Newberry ... 133
  - gaudini (Lesquereux) Berry ... **133**
- *Myrsinites? gaudini* Lesquereux ... 133
- Myrtaceae ... 125–127
- Myrtales ... 125–128
- *Myrtophyllum geinitzi* Heer ... 126
  - *warderi* Lesquereux ... 126

N.

- Nyssa Linné ... 129
  - snowiana Lesquereux ... **129**, *165*

O.

- Onychiopsis ... 53
- Oreodaphne Nees and Martius ... 119–120
  - alabamensis Berry ... **119–120**, *158*
  - shirleyensis Berry, n. sp ... **119**, *158*

P. Page.

- Pachyphyllum araucarium 62
  - rigidum 62
- Paleocassia Ettingshausen 100
  - laurinea Lesquereux 100,*162*
- Paliurus Linné 113
  - upatoiensis Berry 113
- Panax Linné 128
  - cretacea Heer 128,*165*
- Papaverales 95-96
- Papilionaceae 101-103
- Pecopteris neuropteroides 51
- Persea Gaertner 119
  - valida Hollick 119,*160*
- Persoonia Swartz 85-86
  - lesquereuxii Knowlton 85,*153*
    - minor Berry, n. var 86,*153*
- Phaseolites Unger 101
  - elegans Hollick 72
  - formus Lesquereaux 72,101,*161*
  - manhassetensis Hollick 72
- Phegopteris decussata 51
- Phillyrea 108
- Phragmites Trinius 71-72
  - prattii Berry 71-72
- Phyllites asplenioides Berry, n. sp 140-141,*172*
  - *ellipticus* Newberry 134
  - obcordatus Heer 136
  - pistiaeformis Berry, n. sp 140,*168*
  - shirleyensis Berry, n. sp 139-140,*168*
- Phyllocladus 63
  - *subintegrifolius* Lesquereux 57
- Pinus Linné 70
  - delicatulus 64
  - raritanensis Berry 70
  - triphylla 70
  - *sp.* Newberry 70
- Piper 72
- Piperaceae 72
- Piperales 72
- Piperites Goeppert 72
  - tuscaloosensis Berry, n. sp 72,*151*
- Plants, systematic arrangement of 8-11
- Platanaceae 83-85
- Platanales 83-85
- Platanus Linné 83-85
  - *aceroides?* Goeppert var. *latior* Lesquereux 84
  - aspera Newberry 83
  - asperaeformis Berry, n. sp 83,84,*155*
  - kümmelii Berry 84
  - latior (Lesquereux) Knowlton 84
  - *newberryana* Heer 83
  - *primaeva* Lesquereux 84
  - raynoldsii Newberry 83
  - ripleyensis Berry, n. sp 84-85,*171*
  - shirleyensis Berry, n. sp. 49,83-84,*154*
  - sp 85,*170*
- Podocarpus 56,57
- Podozamites Friedrich Braun 55-56
  - marginatus Heer 55-56,71,*145*
- Polemoniales 137
- Polypodiaceae 51-54
- Populites Lesquereux 77-78
  - litigiosus Lesquereux 78
  - tuscaloosensis Berry, n. sp 77-78,*152*
- Populus Linné 77
  - *apiculata* Hollick 137
  - cretacea Knowlton 78
  - hyperborea Heer 77
  - stygia Heer 114
- Primulales 133-134
- Proteaceae 85-86
- Proteales 85-86
- Proteoides Heer? 85
  - conospermaefolia Berry, n. sp 85,*153*
  - *crassipes* Heer 79
  - *daphnogenoides* Heer 76,80,123
  - *longus* Heer 74
- Protodammara Hollick and Jeffrey 60
  - speciosa Hollick and Jeffrey 60
- Protophyllocladus Berry 57-58,63
  - subintegrifolius (Lesquereux) Berry 57-58
- *Prunus? parlatorii* (Heer) Lesquereux 131
- Pseudogeinitzia 65
- Psilotum 50
- Pteridophyta 49-55
- Pterospermites Heer 117
  - carolinensis Berry 117,*164*
- Pyrenomycetes 49

R.

- Ranales 86-95
- Ranunculaceae (?) 86-88
- Raritan flora, relation of the Tuscaloosa flora to 40
- Rhamnaceae 112-115
- Rhamnales 112-115
- Rhamnus Linné 114-115
  - tenax Lesquereux 114-115,*164*
- Ripley formation, distribution of 8,37
  - flora of, correlation of 42-43
    - distribution of species of 43-48
  - localities in, where plants were collected 37-39
  - materials of 37
  - plate showing 32
  - small representation of 7
  - stratigraphic relations of 37
  - studies on 37
- Rosales 96-103
- Rutaceae 104-105

S.

- Sabalites Saporta 72
  - carolinensis Berry 72
  - grayanus Lesquereux 72
  - magothiensis Berry 72
  - sp 72,*150*
- Salicaceae 75-78
- Salicales 75-78
- Salix Linné 75-77
  - *cuneata* Newberry 77
  - eutawensis Berry 76-77
  - flexuosa Newberry 75-76,*152*
  - lesquereuxii Berry 76
  - weekii Newberry 77
  - *proteaefolia* Lesquereux 76
    - *flexuosa* (Newberry) Lesquereux 75
    - *lanceolata* Lesquereux 77
    - *linearifolia* Lesquereux 75
    - *longifolia* Lesquereux 76
- Sanders Ferry Bluff, Ala., section measured and fossil plants collected at 20
- Sapindaceae 111-112
- Sapindales 106-112
- Sapindus Linné 111-112
  - apiculatus Velenovsky 112
  - caudatus Lesquereux 112
  - diversifolius 112
  - morrisoni Heer (Lesquereux MS.) 112
  - variabilis Berry, n. sp 111-112,*166*
- Sapotaceae 135-136
- Sapotacites Ettingshausen 135-136
  - ettingshauseni Berry, n. sp 135,*168*
  - formosus Berry, n. sp 136,*169*
  - haydenii Heer 136
  - shirleyensis Berry, n. sp 135-136,*167*,*168*
- Sassafras Nees 84,120-121
  - acutilobum Lesquereux 120-121
- Selma chalk, distribution of 8
  - nature of 36-37
- Selmer, Tenn., fossil plants collected near 38-39
- Sequoia Endlicher 64-67
  - ambigua Heer 65,66-67,*145*
  - concinna Heer 67
  - *couttsiae* Heer 65
  - *densifolia* Fontaine 65
  - fastigiata (Sternberg) Heer 67
  - heterophylla Velenovsky 65-66
  - *gracilis* Fontaine 66
    - Heer 67
  - *gracillima* (Lesquereux) Newberry 61,69

Page.
Sequoia *heterophylla* Velenovsky 54
  langsdorfii 65
  reichenbachi (Geinitz) Heer 64-65, *145*
  reichenbachi (Geinitz) Heer 61
    longifolia Fontaine 64
  subulata Heer 67
Sequoia ? inferna Ward 65
  sp. Fontaine 65
Shirleys Mill, Ala., plate showing roadside wash in Tuscaloosa formation near 16
  section measured and fossil plants collected at 16-17
Smith, E. A., discoveries by 11-12
Snow plantation, section measured and fossil plants collected on 19-20
Spermatophyta 55, 141
Sphaerites Unger 49
  alabamensis Berry, n. sp 49, 84, *144*
  problematicus 49
  raritanensis 49
Stephenson, L. W., work of 12
Sterculiaceae 117-118
Sterculia Linné 49, 117-118
  minima Berry 117
  mucronata Lesquereux 117
  snowii Lesquereux 117-118
    tennesseensis Berry 117-118, *171*
Systematic arrangement of species represented 8-11

T.

Taeniopteris 55
Taxodium ramosum 69
Ternstroemites 107, 109
Thallophyta 49
Thinnfeldia 63
  lesquereuxiana Heer 57, 58
  subintegrifolia (Lesquereux) Knowlton 57, 58
Thuites alienus Sternberg 67
Thymeleales 118-125
Thyrsopteris 53
Tiliaceae 116-117
Tricalycites Hollick 137-138
  major 138
  papyraceus Hollick 137-138, *167*
Tumion Rafinesque 57, 70
  carolinianum Berry (?) 70
Tuscaloosa, Ala., fossil plants collected at 17-18

Page.
Tuscaloosa formation, distribution of 7, 12
  field work on 11-12
  flora of, composition, origin, and evolution of 22-25
    correlation of 39-41
    distribution of species of 43-48
  lithologic character of 12-13
  plates showing 14, 16
  sections of 14-22
  stratigraphic relations of 14
Tuscaloosa time, climate of 29-30
  deposition in 26
  physiography of 26
Typhaeloipum cretaceum 71

U.

Umbellales 128-130
Urticales 78-83

V.

Vitaceae 115

W.

Ward, L. F., species collected by 12
Whites Bluff, Ala., section measured and fossil plants collected at 21-22
  Tuscaloosa formation in, plate showing 14
Widdringtonia 68, 69
  reichii (Ettingshausen) Velenovsky 69
Widdringtonites Endlicher 67-70
  fastigiatus (Sternberg) Endlicher 67
  ramosus (Fontaine) Barry 68
  reichii (Ettingshausen) Heer 69-70
  subtilis Heer 67-68, *147*
Woodbine sand, flora of, relation of the Tuscaloosa flora to 41

Y.

Yuccites 71

Z.

Zamites tenuinervis Fontaine 56
Zizyphus Linné 112-113
  cliffwoodensis Berry 113
  elegans Hollick 113
  groenlandicus Heer 113
  lamarensis Berry 112-113
  laurifolius Berry 113
  lewisiana 113
  oblongus Hollick 113
  vulgaris Lamarck 113

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BY

EDMUND CECIL HARDER

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CONTENTS.

Page.
Preface, by F. L. Ransome 5
Introduction 7
Acknowledgments 7
The iron-depositing bacteria 8
  General classification and morphology 8
  General physiology 11
Results of the present investigation 13
  Occurrence and morphology of iron-depositing thread bacteria 13
    Crenothrix polyspora Cohn 13
    Leptothrix ochracea Kützing 16
    Gallionella ferruginea Ehrenburg 22
    Spirophyllum ferrugineum Ellis 24
  Other iron-depositing bacteria 29
  Experiments on precipitation of iron from solutions by bacteria 31
    Precipitation of ferric hydroxide and basic ferric salts from ferric ammonium citrate solutions 31
    Precipitation of ferric hydroxide and basic ferric salts from other solutions containing organic iron 36
    Precipitation of ferric hydroxide and basic ferric salts from solutions containing inorganic iron 38
    Precipitation of ferrous sulphide from solutions containing iron 40
  Geologic importance of iron-depositing bacteria 44
    Iron in the earth's crust 44
    Decomposition of iron-bearing minerals 45
    Types of sedimentary iron ores and iron formations 48
      General features 48
      Deposits originally laid down mainly as ferric hydroxide 49
      Deposits originally laid down mainly as ferrous carbonate 54
      Deposits originally laid down mainly as iron silicates 57
      Deposits originally laid down mainly as iron sulphide 60
    Formation of sedimentary iron-bearing deposits 64
      Deposition of iron by mechanical processes 64
      Deposition of iron by chemical processes 64
        Formation of deposits of ferric hydroxide 64
        Formation of deposits of ferrous carbonate 71
        Formation of deposits of iron silicate 73
        Formation ot deposits of iron sulphide 74
      Deposition of iron by biologic agencies 75
        Formation of deposits of ferric hydroxide 75
        Formation of deposits of ferrous sulphide 82
Bibliography 84
Index 87

ILLUSTRATIONS.

Page.

PLATE I. *A*, *a*, Thread of *Crenothrix polyspora*; *b*, Upper portion of the same thread showing conidia in the upper part of the sheath and ordinary vegetative shells in the lower part; *c*, Portions of threads of *Crenothrix polyspora*, showing vegetative cells, conidia, and germination of cells within the sheaths; *B*, Photomicrograph of threads of *Crenothrix polyspora* from city water of Madison, Wis.......... 14

II. *A*, *B*, Photomicrographs of threads of *Crenothrix polyspora* from city water, Madison, Wis........... 15

III. *A*, *B*, Photomicrographs of threads of *Crenothrix polyspora* from city water, Madison, Wis........... 16

IV. *A*, *B*, Photomicrographs of ocherous scum in iron spring near Lake Kegonsa, Madison, Wis........ 17

V. *A*, Photomicrograph of material from 262-foot level, Kennedy mine, Cuyuna, Minn.; *B*, Photomicrograph of ocherous scum on 262-foot level, Kennedy mine, Cuyuna, Minn.................. 18

VI. *A*, *B*, Photomicrographs of ocherous, gelatinous scum from 100-foot level, Federal mine, Hazel Green, Wis.......... 19

VII. *A*, Photomicrograph of ocherous, gelatinous scum from 100-foot level, Federal mine, Hazel Green, Wis.; *B*, Photomicrograph of double twisted ribbon-like form of *Spirophyllum ferrugineum* from city water, Madison, Wis.......... 22

VIII. *A*, Photomicrograph of ocherous scum from 300-foot level, Judson mine, Alpha, Mich.; *B*, Photomicrograph of ocherous scum from 200-foot level, Judson mine, Alpha, Mich.......... 23

IX. *A*, Photomicrograph of ocherous scum from iron spring near Vermilion Lake, Soudan, Minn.; *B*, Photomicrograph of limonite powder from tubercle of iron rust.......... 26

X. *A*, *B*, Cultures showing the precipitation of ferric hydroxide from solutions of ferric ammonium citrate. 27

XI. Cultures showing the effect of sterilization in the precipitation of ferric hydroxide from solutions of ferric ammonium citrate.......... 32

XII. *A*, Petri dishes showing colonies of lower bacteria which precipitate ferric hydroxide from agar containing ferric ammonium citrate; *B*, Photomicrograph of a pure culture of one type of lower bacteria which has the power of precipitating ferric hydroxide from solutions of ferric ammonium citrate... 33

FIGURE 1. Portion of a thread of *Crenothrix polyspora* showing formation of conidia.......... 15

2. Portion of a thread of *Crenothrix polyspora* showing thick coating of ferric hydroxide.......... 16

3. Diagrammatic sketch of *Spirophyllum ferrugineum*, *Gallionella ferruginea*, and *Leptothrix ochracea*... 19

4. Portions of threads of *Leptothrix ochracea* showing straight and curved forms.......... 20

5. Portions of threads of *Leptothrix ochracea*.......... 20

6. Portions of threads of *Leptothrix ochracea*, one of them showing nodular projections.......... 21

7. Loosely twisted ropelike form of *Gallionella ferruginea*.......... 23

8. Closely twisted ropelike form of *Gallionella ferruginea*.......... 23

9. Various forms of *Spirophyllum ferrugineum*.......... 27

10. Irregularly twisted forms of *Spirophyllum ferrugineum*.......... 28

11. Single and double twisted ribbon-like forms of *Spirophyllum ferrugineum*.......... 28

12. Irregularly twisted forms of *Spirophyllum ferrugineum* with granular coatings probably consisting of ferric hydroxide.......... 29

13. Various forms of fossil *Spirophyllum ferrugineum* from tubercle of iron rust.......... 29

14. Various forms of lower bacteria which have the power of precipitating ferric hydroxide from solutions of ferric ammonium citrate.......... 34

PREFACE.

By F. L. Ransome.

The enormous importance of bacteria in all that pertains to the nutrition and well-being of animals and of the higher plants is to-day a matter of wide recognition, even by those whose knowledge of the part played by these minute and wonderful organisms is far from exact. The investigations of Pasteur opened our eyes to their deadly power in disease and their enormous efficiency in processes of fermentation and decay. Realization of the influence of bacteria in affecting the character and fertility of soils, in bringing about rock decay, and in producing other geologic results has come more slowly.

It has been known, however, since 1836 that certain bacteria have the power of withdrawing iron from solution and causing its precipitation as ferric hydroxide. The precipitation of iron sulphide by bacterial processes has also been known for some time. The geologic applications of these discoveries, though predicted by some to be far-reaching, have been rather slowly made, and it is safe to say that many geologists have paid little attention to the possible extent of bacterial action in the deposition of iron ores. Lately, in connection with the studies in the geology of the Coastal Plain, now in progress under the direction of T. W. Vaughan, the part played by bacteria in the deposition of limestones has been specially investigated and found to be important. Similarly when Mr. Harder, who has devoted particular attention for some years to the occurrence of iron ores both in the United States and abroad, was detailed to study the Cuyuna Range, Minn., he found an opportunity in the laboratories of the University of Wisconsin to pursue investigations on the iron-depositing bacteria. The report here presented records the results of this research.

Opinions have differed as to the mode whereby the bacteria withdraw irón from solution. Some investigators have maintained that the deposition of iron hydroxide is one of the vital processes of the organism and as such is effected directly by the action of the living cell; others that the precipitation is purely chemical and is incidental rather than essential to bacterial life; and still others that the accumulation is mechanical, particles of iron hydroxide present in the water being caught and held by mucilaginous parts of the bacteria.

In the course of his work Mr. Harder has found that in addition to the iron-depositing bacteria proper, chiefly the higher or thread bacteria, probably many of the common bacteria of soil and water are active in the precipitation of ferric hydroxide or basic ferric salts from solutions containing iron salts of organic acids. This result is believed to be new. Such bacteria apparently utilize some constituent of the salt other than iron, the iron hydroxide being left as a waste product.

Mr. Harder concludes that, according to present knowledge, there are three principal groups of iron-depositing bacteria—(1) those that precipitate ferric hydroxide from solutions of ferrous bicarbonate, using the carbon dioxide set free and the available energy of the reaction for their life processes; (2) those that do not require ferrous bicarbonate for their vital processes but that cause the deposition of ferric hydroxide when either inorganic or organic iron salts are present; and (3) those that attack iron salts of organic acids, using the organic acid radicle as food and leaving ferric hydroxide, or basic ferric salts that gradually change to ferric hydroxide.

In addition to recording much that is new concerning iron-depositing bacteria, Mr. Harder's report constitutes a valuable critical summary of previous work and should serve a useful purpose in bringing before geologists a digest of practically all that is known on the subject, supplemented by a carefully prepared bibliography.

IRON-DEPOSITING BACTERIA AND THEIR GEOLOGIC RELATIONS.

By Edmund Cecil Harder.

INTRODUCTION.

As early as 1836 it was found by Ehrenberg that organisms play an important part in the formation of ocherous deposits of bog iron ore. Since that time these organisms have been studied by various investigators, who have determined their position in the classification of lower plant forms, have investigated the life histories of some of them, and have studied their morphology and their physiologic processes. Nearly all of this work, however, has been done from the standpoint of the biologist, and the geologic significance has received only minor consideration.

For a number of years I have been engaged in a study of iron ores in different parts of the world and have paid special attention to the mode of origin of these deposits. I have been impressed with the difficulty of explaining the accumulation of large masses of ferric oxide by simple chemical processes. Certain iron-ore deposits, such as limestone-contact ores, ores formed by magmatic segregation, and some types of veins undoubtedly owe their origin to igneous agencies, but there are other deposits of enormous extent, such as sedimentary ores, bog ores, and deposits formed by surface concentration, which have no igneous associations and the origin of which has usually been attributed to simple oxidation and precipitation from solutions containing ferrous iron. It is with reference to the last class that I have endeavored to find a more efficient agent of precipitation under all conditions and have taken up the study of the organisms which precipitate iron oxide.

In order to pursue this investigation intelligently, it was of course necessary to study the organisms both in the laboratory and in the field. It was necessary to show the widespread occurrence of the organisms, as well as to prove their effectiveness in precipitating ferric hydroxide from solution.

In the field work many iron springs, bogs, mines, and streams were examined for the presence of deposits of ferric hydroxide, and when found samples were taken to the laboratory and examined microscopically and some of them chemically. The morphology of the organisms was studied and laboratory cultures were made from them in attempts to study the physiology. Many different iron compounds were used in the laboratory work, organic as well as inorganic, and the activity of the organisms in precipitating ferric hydroxide from each compound was studied.

In general it was found that iron-precipitating organisms were present wherever iron-bearing waters occur, both underground in wells and mines and in surface waters. It was found that the ocherous scums which occur in such localities consisted mainly and in many places entirely of iron-precipitating organisms or their remains. These were found to belong chiefly to the class of organisms known as thread bacteria.

It was determined also that solutions of certain iron compounds, when inoculated with almost any type of natural water or of soil, showed a precipitation of ferric hydroxide by certain types of lower bacteria, thus indicating the almost universal presence in nature of organisms capable of precipitating iron from solution.

ACKNOWLEDGMENTS.

The investigations on which this report is based were made largely in the bacteriologic

laboratory of the Agricultural Experiment Station of the University of Wisconsin. Many helpful suggestions, as well as material aid, were given me by members of the bacteriologic staff of the university. I wish, however, especially to acknowledge my indebtedness to Prof. E. G. Hastings, head of the department of agricultural bacteriology, and to Prof. E. B. Fred, in charge of soil bacteriology, who kindly placed the laboratory and all its facilities at my disposal and who always aided me with willing criticisms throughout the course of the investigations. From Prof. C. K. Leith, of the geologic department of the University of Wisconsin, I received suggestions regarding the method of attack of the geologic problems involved. Prof. W. H. Hunter, of the department of chemistry, University of Minnesota, read and criticised the sections of the report which are largely chemical in nature. Mr. F. T. Thwaites, Dr. W. L. Uglow, Mr. A. D. Wheeler, Prof. E. B. Fred, and many others rendered assistance in collecting material for investigation.

THE IRON-DEPOSITING BACTERIA.

GENERAL CLASSIFICATION AND MORPHOLOGY.

Until recently the term "iron bacteria" was applied to a certain group of filamentous bacteria that have the power of precipitating ferric hydroxide from iron solutions. These organisms were classified by Migula under the general term Trichobacteria or "higher bacteria" to distinguish them from the Haplobacteria or "lower bacteria" to which ordinary coccus, bacillus, and spirillum forms belong. Besides the iron bacteria, such as *Crenothrix*, *Gallionella*, *Spirophyllum*, *Leptothrix*, and *Clonothrix*, there were included under "higher bacteria" certain soil and pathogenic bacteria, such as *Cladothrix*, *Streptothrix*, *Phragmidiothrix*, and *Actinomyces*, and a third group, the "sulphur bacteria," also a higher bacterial type, was classed independently as Thiobacteria. It was supposed that all iron bacteria belonged to the higher type, until about 1908, when Molisch discovered certain coccus forms that had the power of precipitating ferric hydroxide. Still more recently Mumford claims to have isolated a bacillus that has the same power, and it seems quite probable that many other species of both lower and higher bacteria may be found that precipitate ferric hydroxide from iron solutions.

The higher bacteria are distinguished from the lower bacteria by their morphology and their methods of reproduction.[1] Lower bacteria occur as spherical, rod-shaped, or spiral forms and reproduce by simple cell division. Higher bacteria occur as long threads, which are usually composed of many individual cells, and which generally reproduce by the formation of conidia or swarm spores. In some species of higher bacteria conidia or swarm spores are produced by the division of cells which form part of the thread, whereas in other species small protrusions are said to form along the sides of the threads and in time separate themselves from the threads as conidia.

Higher iron bacteria present a variety of forms, such as single threads composed of cylindrical cells placed end to end and generally inclosed in sheaths; ribbon forms, twisted spirally; cylindrical threads showing false branching, or coiled threads or ribbon forms produced by the bending of the filaments in the middle and the twisting of the ends around each other like rope.

According to Migula's general classification, the iron bacteria may be grouped as follows:[2]

A. Eubacteria (true bacteria).
  1. Haplobacteria (lower bacteria).
    a. Coccaceae (2 species of iron bacteria known).
      Siderocapsa treubii.
      Siderocapsa major.
    b. Bacteriaceae (1 species of iron bacteria described).
      Bacillus M. 7.
    c. Spirillaceae (no known species of iron bacteria).

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[1] Benecke, Wilhelm, Bau und Leben der Bakterien, pp. 487–498, Leipzig, 1912.

Rullman, W., Eisenbakterien, Cladotricheen, Streptotricheen, und Actinomyceten, in Lafar's Handbuch der technischen Mykologie, Auflage 2, Band 3, pp. 190–214, Jena, 1904–5.

Migula, W., System der Bakterien, Band 2, p. 1031, Jena, 1897–1900.

Molisch, Hans, Die Eisenbakterien, Jena, 1910.

Ellis, David, The iron bacteria: Sci. Progress, vol. 10, pp. 374–392, 1916.

[2] Adapted in part from Migula and in part from Benecke and Ellis.

- A. Eubacteria (true bacteria)—Continued.
    - 2. Trichobacteria (higher bacteria) (numerous species of iron bacteria).
        - a. Thread bacteria consisting of sheaths with included cells generally plainly visible; reproduction by internally produced conidia or by the separation of motile or nonmotile cells.
            - Crenothrix polyspora.
            - Cladothrix dichotoma.
            - Clonothrix fusca.
            - Leptothrix ochracea (Chlamydothrix ochracea).
            - Chlamydothrix sideropous (Leptothrix sideropous).
            - Megalothrix discophora.
        - b. Thread bacteria showing no division into separate cells; method of reproduction not definitely established but supposed to be by breaking off of parts of threads and perhaps by external abstriction of conidia.
            - Gallionella ferruginea (Chlamydothrix ferruginea).
            - Spirophyllum ferrugineum.
            - Nodofolium ferrugineum.
            - Conidiothrix. (?)
- B. Thiobacteria (sulphur bacteria) (no known species of iron bacteria).

Siderocapsa was found by Molisch[1] to occur on the submerged leaves or stems of certain water plants on which it exists in the form of little irregular ringlike colonies. Frequently it forms a brown incrustation covering the entire submerged portion of the plants. It is a common coccus form and is said to be one of the most abundant of water bacteria. It is believed by Molisch to be an important agent in the formation of bog iron ores.

Bacillus M. 7 was discovered by Mumford[2] during an examination of iron-bearing colliery waters in England. He examined the brownish ocherous scum which formed in a basin into which the mine waters emptied and found that it consisted of a mass of ferric hydroxide of fine granular texture with some scattered threads of higher iron bacteria. After various inoculations of this granular material in culture media a bacillus was isolated which produced an enzyme that had the power of precipitating ferric hydroxide from either ferrous or ferric solutions. Mumford states that he succeeded in isolating the enzyme from the organism by filtration.

Crenothrix[3] is the largest of the iron bacteria and is found most commonly at the bottoms of wells and in city water pipes. Less than 2 parts of iron per million in water is sufficient to support the activity of *Crenothrix*.

In its manner of growth and reproduction, *Crenothrix* is one of the most interesting of the iron bacteria. It is sessile; the attached end is thin and the organism gradually thickens toward the free end. The separate cells that make up a thread of *Crenothrix* are clearly distinguishable, being rod shaped and placed end to end in a sheath. Toward the upper end of the filament the cells are seen to divide, at first transversely and then longitudinally, so that a large number of small spherical cells are formed near the upper end of the filament. These are the conidia, which leave the parent sheath and form new threads. Frequently conidia are prevented from leaving the sheath, and then they germinate within the sheath and thrust their filaments through the walls, giving the appearance of numerous little branches extending from the parent filament.

Clonothrix[4] and *Cladothrix*[5] are forms related to *Crenothrix* but differ from it in showing false branching. This is caused by one cell pushing by the next above it and then dividing and pushing its way through the sheath. *Clonothrix* reproduces by the formation of conidia resembling those of *Crenothrix* and by vegetative cells which slip out of the sheath. The threads are similar to those of *Crenothrix* but taper toward the free end while those of *Crenothrix* thicken toward the free end. *Cladothrix* is primarily a soil organism and does not belong to the iron bacteria proper, but it is capable of depositing ferric hydroxide on its sheath. It reproduces by motile and nonmotile conidia, resembling vegetative cells, which either leave the ends of the threads or are set free by the breaking up of the threads.

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[1] Molisch, Hans, *Siderocapsa treubii* Molisch, eine neue weitverbreitete Eisenbakterie: Centralbl. Bakteriologie, Abt. 2, Band 29, p. 243, 1911; Die Eisenbakterien, Jena, 1910.

[2] Mumford, E. M., A new iron bacterium: Chem. Soc. Jour., vol. 103, pp. 645–650, 1913.

[3] Cohn, F. J., Ueber den Brunnenfaden (*Crenothrix polyspora*) mit Bemerkungen ueber die mikroskopische analyse des Brunnenwassers: Beitr. Biologie Pflanzen, Band 1, Heft 1, pp. 108–131, 1875.

Zopf, W., Entwicklungsgeschichtliche Untersuchungen über *Crenothrix polyspora*, die Ursache der Berliner Wasserkalamität, Berlin, 1879.

Rössler, O., Ueber Kultivierung von *Crenothrix polyspora* auf festem Nährboden: Archiv Pharmacie, Band 233, pp. 189–191, 1895.

Adler, Oscar, Ueber Eisenbakterien und ihrer Beziehung zu den therapeutisch verwendeten natürlichen Eisenwässern: Centralbl. Bakteriologie, Abt. 2, Band 11, pp. 215–219, 277–278, 1903–4.

Schorler, B., Beiträge zur Kenntnis der Eisenbakterien: Centralbl. Bakteriologie, Abt. 2, Band 12, pp. 681–695, 1904.

Beythien, Hempel, and Kraft, Beiträge zur Kenntnis des Vorkommens von *Crenothrix polyspora* in Brunnenwässern: Zeitschr. Untersuchung Nahrungs- und Genussmittel, 1904, Heft 4, p. 215.

Rullmann, W., Ueber Eisenbakterien: Centralbl. Bakteriologie, Abt. 2, Band, 33, pp. 277–289, 1912.

[4] Schorler, B., Beiträge zur Kenntnis der Eisenbakterien: Centralbl. Bakteriologie, Abt, 2, Band 12, pp. 681–695, 1904.

[5] Cohn, F. J., Untersuchungen ueber Bakterien: Beitr. Biologie Pflanzen, Band 1, Heft 3, p. 185, 1875.

Zopf, W., Zur Morphologie der Spaltpflanzen, Leipzig, 1882.

Ellis, David, An investigation into the life history of *Cladothrix dichotoma:* Roy. Soc. Proc., B, vol. 85, pp. 344–358, 1912.

Leptothrix[1] is a simple thread form, usually free but sometimes attached at one end. The threads are straight or curved. They generally have the same width throughout and consist of a sheath inside of which rod-shaped cells lie end to end. Only rarely, however, can the cells in the sheath be distinguished, due to the coloring in the sheath, and besides many dead, empty sheaths are mixed with the living organisms. The sheaths are yellowish brown from ferric hydroxide. The organism commonly reproduces by fragmentation but may reproduce also by the separation of vegetative cells and by swarm cells.

Leptothrix is found abundantly in chalybeate springs, where it forms soft fluffy botryoidal masses attached to the bottom or sides of the basins. Less commonly it occurs underground in mines or tunnels where iron-bearing waters issue from the rocks. The occurrence of iron bacteria in deep mines has to my knowledge not previously been mentioned in the literature.

Megalothrix discophora, a form recently described by Schwers,[2] somewhat resembles *Leptothrix* but differs from it in being thicker and in possessing a very thick sheath. Inside of this sheath is a narrow canal in which long cylindrical cells are occasionally seen. The threads have a holdfast at one end by means of which they attach themselves to foreign objects. Some of them show dichotomous branching.

Gallionella[3] in its typical form consists of spiral threads coiled together into double or quadruple coils like rope. The individual threads, which are yellow to brown, are cylindrical like those of *Leptothrix* but are generally much thinner. Cells have not been distinguished within them. Though usually tightly wound into coils, loosely wound threads are frequently seen and occasionally even single spiral threads.

Gallionella is said to occur in iron-bearing surface waters with *Leptothrix*, but more commonly it is associated with *Spirophyllum* in iron-bearing well waters and in certain mines where iron-bearing waters issue from the walls. In such places *Gallionella* and *Spirophyllum* form soft, spongy ocherous masses on the walls beneath the openings where iron waters issue.

Spirophyllum[4] is perhaps the most abundant of the iron thread bacteria. It has the form of flat ribbon-like or tapelike threads twisted in the form of spirals. These spiral bands may occur as single filaments or they may be coiled together as in *Gallionella*. Reproduction in *Spirophyllum* is commonly by fragmentation but is said to take place also by means of conidia, which form budlike projections on the flat sides of the bands. This method of reproduction is questioned by some investigators.

Spirophyllum is abundantly distributed in nature. It occurs with *Leptothrix* in chalybeate springs and other iron-bearing surface waters, alone or with *Gallionella* or *Leptothrix* in iron-bearing mine waters, and with *Crenothrix* in city water pipes. In the latter it occasionally becomes so abundant as to cause turbidity of the water and even a blocking of the pipes due to the deposition of ferric hydroxide.

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[1] Kützing, Phycologia generalis, p. 198, 1843.

Migula, W., System der Bakterien, Band 2, p. 1031, Jena, 1900.

Winogradsky, S., Ueber Eisenbakterien: Bot. Zeitung, Band 46, pp. 262–270, 1888.

Schorler, B., Beiträge zur Kenntnis der Eisenbakterien: Centralbl. Bakteriologie, Abt. 2, Band 12, pp. 681–695, 1904.

Ellis, David, A contribution to our knowledge of the thread bacteria: Centralbl. Bakteriologie, Abt. 2, Band 19, pp. 502–518, 1907; Band 26, pp. 321–329, 1910.

Molisch, Hans, Die Eisenbakterien, Jena, 1910.

[2] Schwers, Henri, *Megalothrix discophora*, eine neue Eisenbakterie: Centralbl. Bakteriologie, Abt. 2, Band 33, pp. 273–276, 1912.

[3] Ehrenburg, D. C. G., Vorläufige Mittheilungen ueber das wirklige Vorkommen fossiler Infusorien und ihre grosse Verbreitung: Poggendorf's Annalen, Band 38, pp. 213–227, 1836.

Migula, W., Ueber *Gallionella ferruginea* Ehrenburg: Deutsch. bot. Gesell. Ber., Band 15, p. 321, 1897.

Kützing, Species algarum, p. 250, 1849.

Ellis, David, A contribution to our knowledge of the thread bacteria: Centralbl. Bakteriologie, Abt. 2, Band 19, pp. 502–518, 1907; Band 26, pp. 321–329, 1910.

Schorler, B., Die Rostbildungen in den Wasserleitungsröhren: Centralbl. Bakteriologie, Abt. 2, Band 15, pp. 564–568, 1906.

[4] Ellis, David, On the discovery of a new genus of thread bacteria (*Spirophyllum ferrugineum* Ellis): Roy. Soc. Edinburgh Proc., vol. 27, pt. 1, pp. 21–34, 1907; A contribution to our knowledge of the thread bacteria: Centralbl. Bakteriologie, Abt. 2, Band 19, pp. 502–518, 1907; Band 26, pp. 321–329, 1910.

Lieske, R., Beiträge zur Kenntnis der Physiologie von *Spirophyllum ferrugineum* Ellis: Jahrb. wiss. Botanik, Band 49, pp. 91–127, 1911.

Nodofolium[1] is described by Ellis as being related to *Spirophyllum*. It is said to consist of flat elliptical disks placed end to end so that each succeeding one is at right angles to the last, the whole forming a chain. Investigators who do not follow Ellis claim that *Nodofolium* is simply a form of *Spirophyllum*.

The name *Conidiothrix* is suggested by Benecke[2] for a simple thread form resembling *Leptothrix* which has been described by Ellis. It differs from *Leptothrix* in that its cell structure is not visible and in that it reproduces by conidia which form projections on the outside of the sheath. This form has not been definitely identified.

The separation of the higher iron bacteria into two groups, one characterized by internally produced conidia and the other by the external abstriction of conidia, seems to me questionable. Several investigators doubt the occurrence of external conidia, Ellis being practically the only author on record who states definitely that he has seen their formation and germination. In my work, during which I have examined iron bacteria from many different localities, I have never certainly identified external conidia, and although I have often noted nodular projections or attached bodies on bacterial threads, most of these projections have turned out to be granules of ferric hydroxide or other foreign particles. It is not impossible, however, that further work may prove Ellis's contention to be correct and that other investigators will be able to definitely confirm this method of reproduction among iron bacteria.

A number of other organisms besides iron bacteria are known which deposit ferric hydroxide in their coatings or in certain parts of their bodies.[3] Among these are included algae, such as *Psichohormium*, *Oedogonium*, *Euglena*, *Closterium*, and *Trachelomonas*, as well as protozoa, such as *Rhipidodendron*, *Phallansterium*, *Spongomonas*, *Carchesium*, and especially a certain flagellate called *Anthophysa*, a branch-like organism which commonly becomes heavily incrusted with ferric hydroxide. In my own work I have also found that the mycelia of various fungi often become impregnated with or coated by ferric hydroxide.

GENERAL PHYSIOLOGY.

Several explanations have been offered for the deposition of ferric hydroxide by iron bacteria. Some investigators believe that the precipitation is merely a chemical process, in no way connected with the internal activity of the cell, whereas others claim that the process is one of oxidation of ferrous to ferric compounds and that it is necessary for the life processes of the organisms.

Among the first to study the activities of iron-depositing thread bacteria were Cohn and Zopf. Cohn[4] believed that the ferric hydroxide was deposited as a result of the activity of living cells and that the deposition occurred in the same manner as the deposition of silica takes place in the tests of diatoms. Zopf[5] some years later stated that he found ferric hydroxide being deposited on empty sheaths from which all living cells had been removed. He was of the opinion, therefore, that the storing up of ferric hydroxide in the sheaths was merely the result of mechanical processes, the iron compounds being taken up by a mucilaginous coating on the sheaths.

Later Winogradsky[6] investigated the physiology of iron bacteria. His experiments were conducted with *Leptothrix*, and in a publication of his results in 1888 he states that *Leptothrix* will live and grow only in solutions in which iron is present in the ferrous form, and that only where living cells are present in a sheath is there any coloration of the sheath due to the oxidation of ferrous salts. He also found that the sheaths would not take up mechanically any ferric hydroxide which may be present in the solution and believed that the coloration is due to ferric hydroxide being given off by the cells and caught in the sheath which incloses them.

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[1] Ellis, David, A contribution to our knowledge of the thread bacteria: Centralbl. Bakteriologie, Abt. 2, Band 26, pp. 321–329, 1910.

[2] Benecke, Wilhelm, Bau und Leben der Bakterien, pp. 489–492, Leipzig, 1912.

[3] Molisch, Hans, Die Eisenbakterien, pp. 53–58, 1910.

[4] Cohn, F. J., Ueber den Brunnenfaden (*Crenothrix polyspora*) mit Bemerkungen ueber die mikroskopische Analyse des Brunnenwassers: Beitr. Biologie Pflanzen, Band 1, Heft 1, pp. 108–131, 1875.

[5] Zopf, W., Zur Morphologie der Spaltpflanzen, Leipzig, 1882.

[6] Winogradsky, S., Ueber Eisenbakterien: Bot. Zeitung, Band 46, pp. 262–270, 1888.

He concludes from this that the oxidation of ferrous compounds to form ferric hydroxide is necessary for the life and growth of the organisms and that this process furnishes energy to the cell for the assimilation of food. The food consists of organic compounds present in the water. Only a small amount of organic matter, however, was found to be necessary to sustain life. Winogradsky worked with solutions of ferrous carbonate ($FeCO_3$).

Molisch[1] (1892 and 1910), in a series of experiments, proved that *Leptothrix* will grow profusely in an iron-free medium, forming perfectly colorless sheaths. He found that peptone solutions were especially favorable for its development. If either iron or manganese compounds were present in the solutions, however, he found that they were oxidized and taken up by the sheaths. Likewise, Molisch states that *Leptothrix* forms thicker and longer threads when iron or manganese is present in solution and that sheaths containing live cells accumulate ferric hydroxide more abundantly. However, threads in which the cells have been killed by boiling in water are still capable of taking up ferric hydroxide in their sheaths. He determined further that where there was little chance of oxidation, a ferrous compound would accumulate in the sheath and cause the same luxuriant growth as ferric hydroxide. Therefore he concludes that though these organisms show a marked attraction for iron or manganese compounds, the reason for this is a physicochemical one, and the change of ferrous to ferric compounds is due to simple oxidation and is not connected with the life processes of the cells as was claimed by Winogradsky. That dead, empty sheaths do not take up ferric hydroxide to a marked extent he explains by stating that living cells probably have some influence in keeping the sheath in a condition in which it is able to accumulate more material.

James Campbell Brown[2] made some interesting observations on the black slime which collects in pipes, culverts, and other water channels. He finds that it consists mainly of a mixture of ferric hydroxide, manganese oxide, and organic matter and that it contains among other organisms abundant iron-depositing thread bacteria. He states that such slimes form only in acid waters, that they do not occur in neutral or alkaline waters, and that they frequently form in waters in which iron is not present as ferrous bicarbonate.

From his observations he concludes that where black slimes form in water channels iron is carried in solution in the form of soluble organic salts. He believes that the iron-depositing thread bacteria which are found in the slimes use the organic salts as food and set free ferric hydroxide, which is then deposited in the sheaths. The manganese oxide he believes is a simple oxidation product. A small amount of ferric hydroxide is perhaps also formed by simple oxidation and becomes mixed with the slime.

Ellis[3] in 1907 published a paper in which he sets forth his belief that the deposition of ferric hydroxide around bacterial threads is purely mechanical. He does not believe that Winogradsky had a valid basis for his conclusions and thinks with Zopf that the accumulation is the result of the catching up of particles of ferric hydroxide present in the water by a mucilaginous covering which surrounds the sheaths. The presence of such a mucilaginous coating was demonstrated by Zopf[4] in 1878. Ellis, like Winogradsky, worked principally with *Leptothrix* but also examined cultures of *Spirophyllum* and *Gallionella*, and believes that what is true of *Leptothrix* is true of all iron bacteria.

Lieske[5] in a report published in 1911 gives the results of various experiments made with *Spirophyllum*. He finds that this organism will grow only in solutions containing ferrous carbonate and that other ferrous salts will not take the place of ferrous carbonate. He finds not only that much organic matter impairs the growth of *Spirophyllum* and may stop it altogether, but that where abundant carbon dioxide is present in water and organic matter is entirely absent this organism will grow profusely. He concludes from this that the carbonate radicle furnishes food for *Spirophyllum* and that the latter oxidizes ferrous carbonate to ferric hydroxide mainly for the purpose of obtaining carbon. He believes with Winogradsky that the oxidation may furnish energy to the organism for the assimilation of food, which in this case is carbon dioxide.

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[1] Molisch, Hans, Die Eisenbakterien, pp. 44–52, Jena, 1910; Die Pflanze in ihren Beziehungen zum Eisen, p. 71, Jena, 1892.

[2] Brown, J. C., Deposits in pipes and other channels conveying potable water: Inst. Civ. Eng. Proc., vol. 156, Sess. 1903–4, pt. 2, pp. 1–17, 1904.

[3] Ellis, David, A contribution to our knowledge of the thread bacteria: Centralbl. Bakteriologie, Abt. 2, Band 19, pp. 502–518, 1907.

[4] Zopf, W., Entwicklungsgeschichtliche Untersuchungen ueber *Crenothrix polyspora*, die Ursache der Berliner Wasserkalamität, Berlin, 1879.

[5] Lieske, Rudolf, Beiträge zur Kenntnis der Physiologie von *Spirophyllum ferrugineum* Ellis: Jahrb. wiss. Botanik, Band 49, pp. 91–127, 1911.

Lieske gives the following reaction as indicating what probably takes place in this process of oxidation:

$$\underset{368\text{ kg. cal.}}{2FeCO_3} + \underset{207\text{ kg. cal.}}{H_2O} = \left.\underset{398\text{ kg. cal.}}{Fe_2(OH)_6} + \underset{206\text{ kg. cal.}}{2CO_2}\right\} + 29\text{ kg. cal.}$$

Mumford[1] in a short paper published in 1913 describes experiments with *Bacillus M. 7*, a new type of iron bacterium discovered by him. He states that this organism forms a precipitate of ferric hydroxide in ferric as well as ferrous solutions. Organic compounds were used as a source of food. He found that ferric hydroxide was precipitated only under aerobic conditions and that under anaerobic conditions the ferric hydroxide already precipitated was simply somewhat dehydrated, forming limonite or bog ore. He ascribed these reactions to an enzyme which, he states, he succeeded in isolating from the organisms by filtration. This filtered enzyme produced the same phenomena as the living organism.

It is difficult to reconcile these various conflicting hypotheses regarding the physiologic activity of iron-depositing bacteria. Some of the discrepancies can probably be explained by the fact that some of the observers were working with different organisms and under different conditions, but other discrepancies seem to be due to faulty observation. Molisch worked with *Leptothrix* and found that it required organic matter but that it did not require iron in solution. Lieske, on the other hand, in working with *Spirophyllum*, finds that it requires ferrous carbonate in solution but that it can live in the absence of organic matter. Here are two different organisms that clearly show entirely different characteristics. Such an explanation, however, does not apply to the discrepancies between the observations of Molisch and Winogradsky. Both of these investigators were working with *Leptothrix* and yet their results differ radically. Similarly, James Campbell Brown, who finds that iron-depositing thread bacteria grow in solutions containing no ferrous bicarbonate, concludes that iron-precipitating organisms do not use inorganic iron compounds but must have soluble organic iron salts in solution. Such a conclusion is speculative, for although Molisch has shown that *Leptothrix* will thrive on certain organic iron salts in solution, Lieske has proved that *Spirophyllum* undoubtedly will not. Besides, very little is known definitely about the carrying of iron in solution in natural waters in the form of soluble organic salts, although indications of this possibility exist. The observations of Mumford also are open to doubt, for the reason that he did not use control cultures and the possibility of chemical oxidation taking place in his ferrous solutions has not been eliminated.

In general it seems reasonable to believe that certain iron-depositing organisms, such as *Spirophyllum*, require ferrous bicarbonate in solution and can not live without it; that others, such as *Leptothrix*, can live without any iron compounds, but if they are present can use either ferrous bicarbonate or soluble organic iron salts; and that still others, such as various lower bacteria (see pp. 29–31) will use the organic radicle of certain soluble organic iron salts when present but can not utilize any inorganic iron salts. The physiologic activity of iron-depositing organisms will be frequently referred to in the following discussion.

RESULTS OF THE PRESENT INVESTIGATION.

OCCURRENCE AND MORPHOLOGY OF IRON-DEPOSITING THREAD BACTERIA.

Crenothrix polyspora Cohn.

The common habitat of *Crenothrix polyspora* is in wells and in city water pipes in localities where the water contains an appreciable amount of iron in solution. It is so common in many places both in the United States and in Europe that it has become known as the "water-pest bacterium," because of its tendency to produce turbidity in water due to the precipitation of ferric hydroxide. In Germany *Crenothrix* is commonly known as "Brunnenfaden" (well thread), on account of its frequent occurrence in wells, although various German investigators mention its occurrence in streams, canals, and other water bodies as well. In wells *Crenothrix* is described as occurring in dark-brown or black scumlike masses at the bottom or along the sides. The newer outer portions of such masses are usually lighter colored than the older portions. In distributing pipes *Crenothrix* occurs in association with *Spirophyllum* and *Gallionella*, which are attached to the interior of the pipes, where they often form hard iron crusts.

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[1] Mumford, E. M., A new iron bacterium: Chem. Soc. Jour., vol. 103, pp. 645–650, 1913.

Most of the *Crenothrix* cultures for my investigations were obtained from the city water of Madison, Wis. (See Pls. I, II, and III.) This water, although its iron content is comparatively low, contains an abundance of *Crenothrix*, as well as *Gallionella* and *Spirophyllum*. It is obtained from several deep wells which penetrate the Cambrian sediments and end in the underlying granite more than a thousand feet below the surface. The following is a partial analysis of the mineral constituents of Madison city water by W. G. Crawford, of the University of Wisconsin:

Partial analysis of city water from Madison, Wis.

	Parts per million.
Silica (SiO_2)	10.3
Ferric oxide (Fe_2O_3)	1.8
Calcium (Ca)	62.5
Magnesium (Mg)	36.4
Bicarbonate radicle (HCO_3)	324.5
Sulphate radicle (SO_4)	15.5
Chlorine (Cl)	.4
Free carbon dioxide (CO_2)	5.8

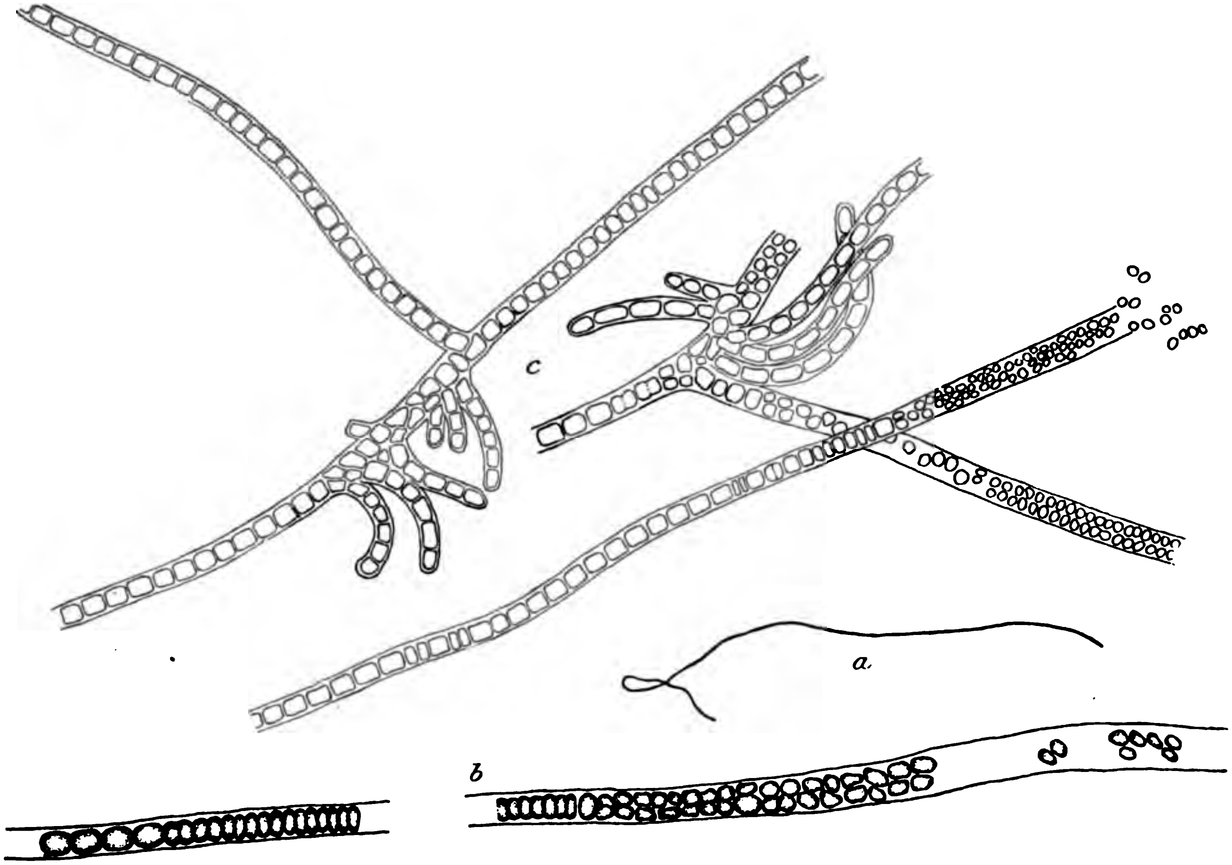
The analysis shows that the water contains an abundance of calcium and magnesium carbonates and is a typical "hard water." No attempt is made to combine the constituents into salts. The usual method of making such combinations is at best artificial, and here it seems preferable to show the actual facts. The carbon dioxide in the bicarbonate radicle is that which is combined with the bases, such as calcium, magnesium, and iron, to form carbonates or bicarbonates. The carbon dioxide present as free gas is shown separately. The sulphate radicle, which forms an appreciable percentage, is probably present combined with calcium and iron. The iron present is shown as ferric oxide, although in the water practically all of it is present in the ferrous form, mainly as carbonate or bicarbonate and perhaps as sulphate. It is not possible to tell in what relative proportion these salts occur. The actual quantity of metallic iron present in the water amounts to 1.26 parts per million. This seems a very small amount to cause the growth of iron bacteria, yet it was sufficient to produce turbidity in the water upon standing with free access of oxygen.

Crenothrix polyspora is easily obtained from city water, in which it is present, by filtering. The best method is to attach a thoroughly cleaned and sterilized Berkefeld porcelain filter to a screw spigot and allow the water to pass through for 24 to 36 hours. At the end of this period a thin yellowish-brown deposit of ferric hydroxide will be found to coat the filter, unless the water is turbid, and then a heavy blackish-brown coating may be found. The latter, however, is not so desirable for cultures.

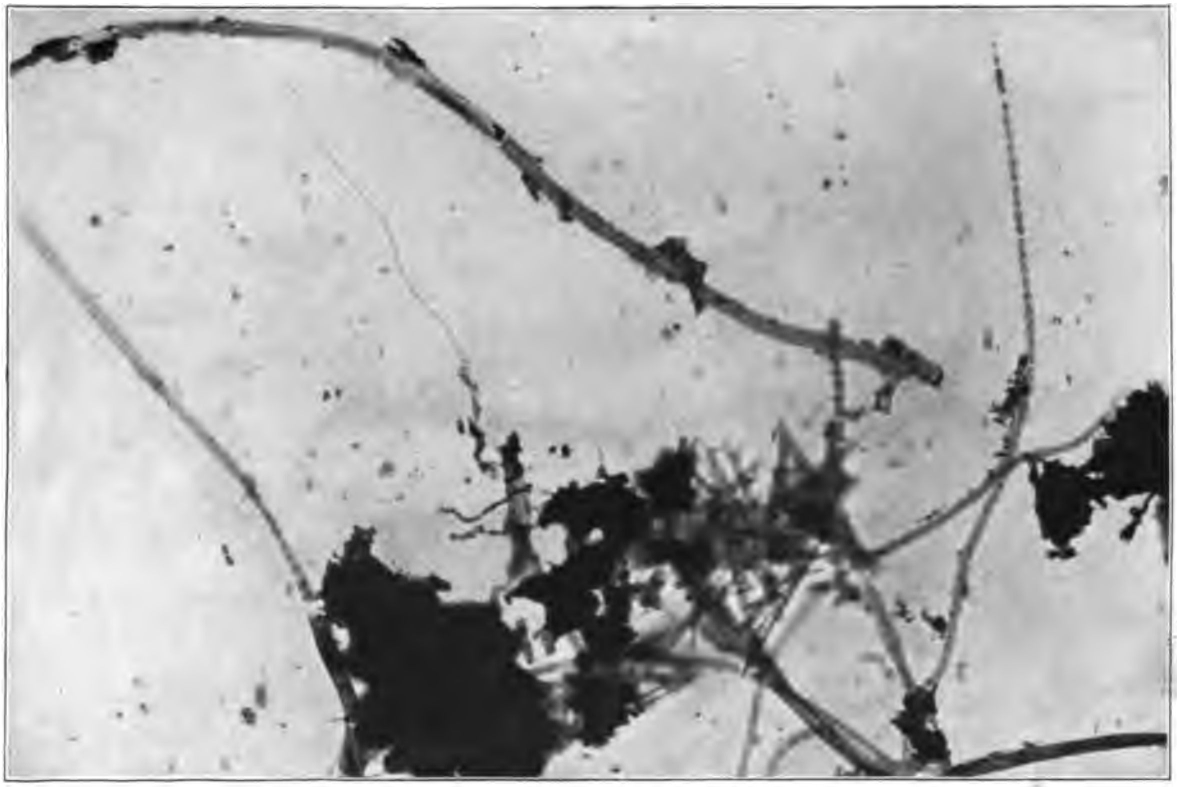
The filter, after being removed from the spigot, should be immersed in a sterile solution of well water to which has been added, previous to sterilizing, about 0.1 per cent of powdered ferrous carbonate ($FeCO_3$) and about the same amount of sodium or potassium acetate. This solution should be placed in a large beaker (preferably about 3,000 cubic centimeters), and the filter should be suspended so as to hang freely in the liquid. The beaker should be covered in order to prevent dust from settling on the solution.

For incubating the cultures it is best to place them in an ice chest at a temperature of about 6° to 8° C., for this retards the growth of molds, which otherwise rapidly develop on the surface of the filter and prevent the growth of other organisms. Within a few days *Crenothrix* will be found to develop on the filter and can be obtained for examination under the microscope by scraping material from the surface of the filter with a platinum needle. Impure cultures prepared in this manner may be kept for several weeks.

Pure cultures of *Crenothrix polyspora* are difficult to obtain, not only because of the difficulty of finding artificial media in which *Crenothrix* will grow but also because the threads are so large that it is difficult to make

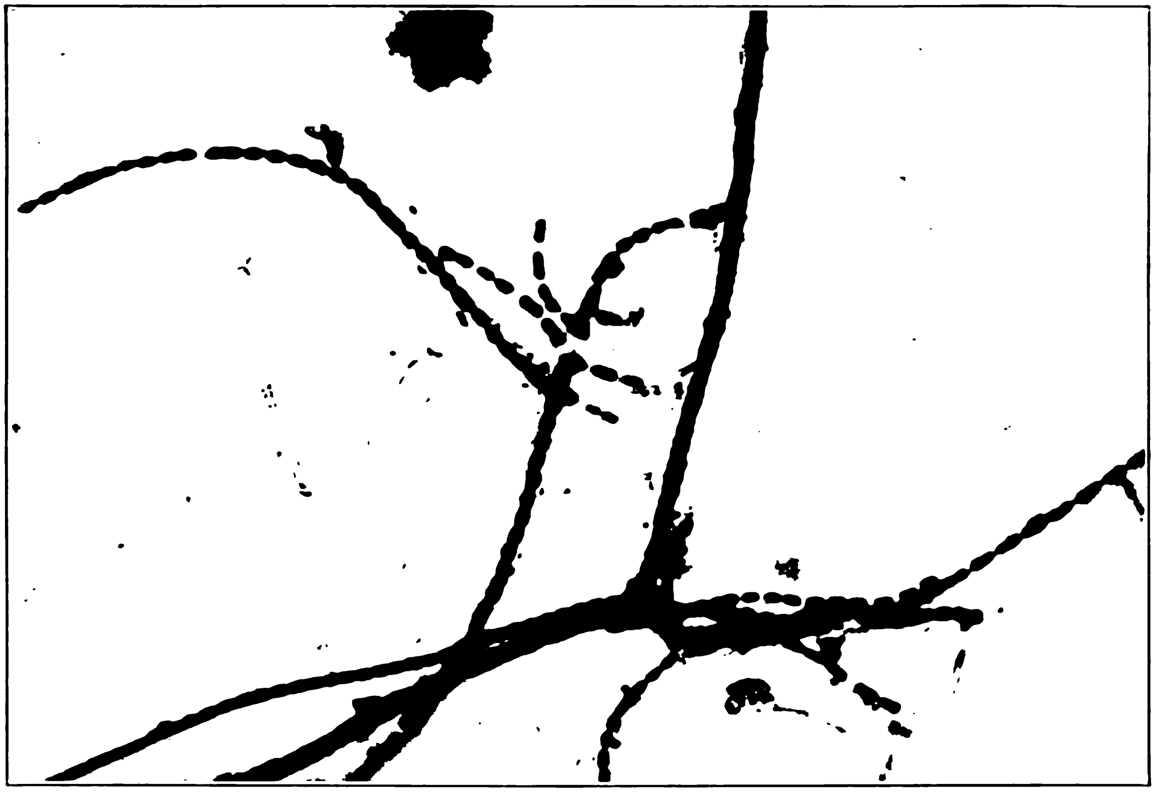


A. *a*, THREAD OF CRENOTHRIX POLYSPORA, ×80; *b*, UPPER PORTION OF THE SAME THREAD, ×940, SHOWING CONIDIA IN THE UPPER PART OF THE SHEATH AND ORDINARY VEGETATIVE CELLS IN THE LOWER PART; *c*, PORTIONS OF THREADS OF CRENOTHRIX POLYSPORA, ×550, SHOWING VEGETATIVE CELLS, CONIDIA, AND GERMINATION OF CELLS WITHIN THE SHEATHS.



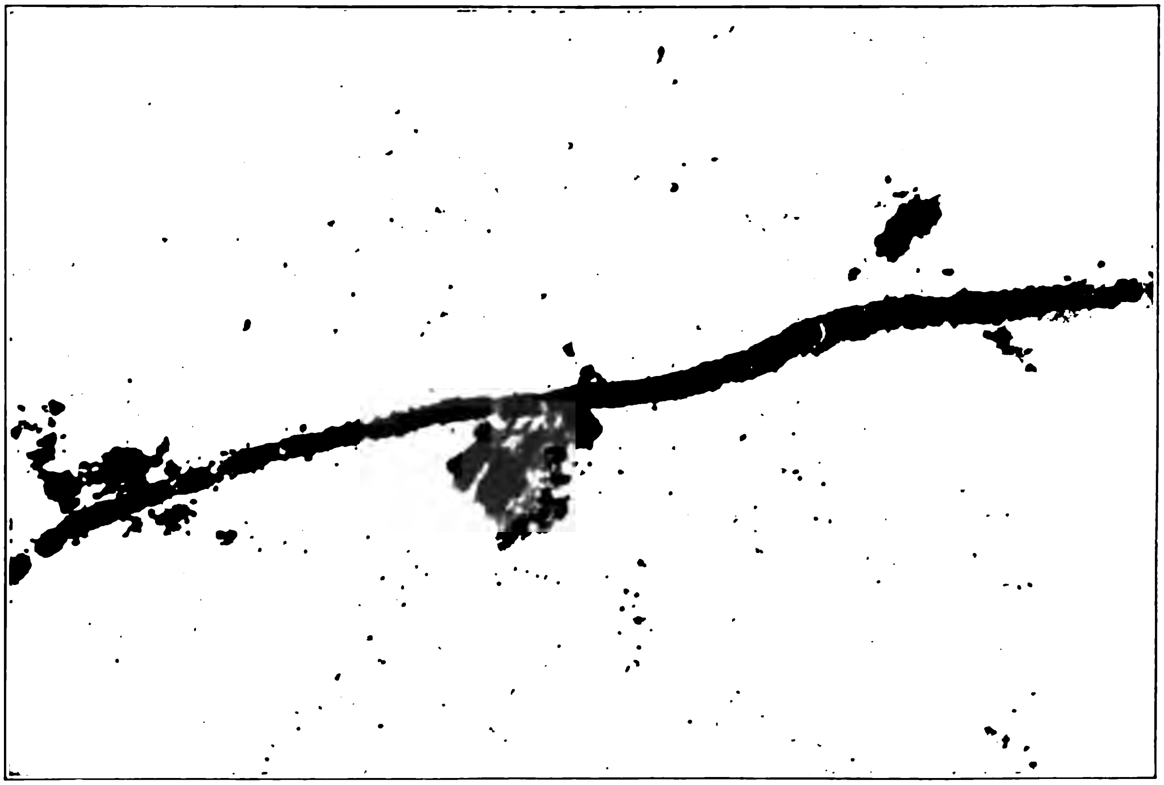
B. PHOTOMICROGRAPH OF THREADS OF CRENOTHRIX POLYSPORA FROM CITY WATER, MADISON, WIS., ×450.

Material obtained on filter. Some threads show ordinary vegetative cells; others show conidia. Stained with gentian violet.



A. PHOTOMICROGRAPH OF THREADS OF CRENOTHRIX POLYSPORA FROM CITY WATER, MADISON, WIS., × 450.

Material obtained on filter. Threads show vegetative cells and germination of cells within the sheath. Stained with carbol fuchsin.



B. PHOTOMICROGRAPH OF THREAD OF CRENOTHRIX POLYSPORA FROM CITY WATER, MADISON, WIS., × 640.

Shows ordinary vegetative cells and disklike cells formed by transverse division of ordinary cells. Shows also a thickening of the thread toward the upper part of the sheath (on the right). The sheath is faintly seen. Stained with gentian violet.

transfers of the organism without taking other forms which may be attached to them. Rössler[1] claims to have obtained pure cultures of *Crenothrix* on sterilized bricks immersed in water to which a small amount of ferrous sulphate was added. However, he does not state how he obtained his material for inoculation nor does he mention the presence in the solution of any other nutrient material besides ferrous sulphate. Molisch[2] repeated these experiments but without success, and states that he has not been able to cultivate *Crenothrix* in any kind of artificial media even in impure cultures. He concludes that the growth of *Crenothrix* is dependent on special conditions which are difficult to reproduce in the laboratory. Recently, however, Rullmann[3] succeeded in producing cultures of *Crenothrix* both in liquid media and on agar plates.

As already mentioned, *Crenothrix* occurs as unbranched threads (see Pls. I, II, and III, and figs. 1 and 2), one end of which is attached while the other end is free. A gradual thickening takes place from the attached end to the free end with the result that the free end commonly has three or four times the width of the attached end. The individual cells making up the thread suffer the same decrease in width toward the attached end as the sheath inclosing them and hence appear much more elongated at the attached end.

Crenothrix threads are generally colorless and can only be seen with the microscope when the light is greatly reduced. The separate cells are then clearly distinguishable, as is also the sheath which incloses them. The threads vary in length up to several millimeters, but usually under the microscope one does not see threads that exceed 0.5 millimeter in length. In diameter the threads vary between 2 and 9 micra.[4] Only very young threads or the attached ends of the older threads are as thin as 2 micra, and the maximum diameter, 9 micra, is only found in old sheaths when complete formation of conidia has taken place. The diameter of the threads is ordinarily between 3 and 5 micra near the attached end and between 5 and 6 micra at the free end.

The individual vegetative cells (see Pls. I, *A*, II, *B*, and III, *B*) forming the thread range in width from 2 to 5 micra and in length from 2 to 9 micra. The normal shape of the cells is cylindrical, the length being about twice the diameter. Just after cell division, however, which takes place transversely, the length and diameter are nearly equal. In the lower portion of the thread many of the cells have a rectangular outline with the square ends, whereas in the upper part of the thread the ends are rounded. The sheath inclosing the cells is generally thin, in some specimens being hardly distinguishable from the cell walls themselves.

In spore formation the division of cells takes place both transversely and longitudinally—that is, there is cell division in three directions. (See Pls. I and II, *A*.) This process results in the formation of a large number of spherical or more or less irregular spores or conidia, which increase in size somewhat after their formation so that different spores range in diameter from less than 2 micra to 4 micra. The division of cells into spores as a rule takes place at the end of the thread, but frequently it occurs at different points in the upper part of the thread, so that small round spores may be inclosed between cells as yet undivided. (See fig. 1.)

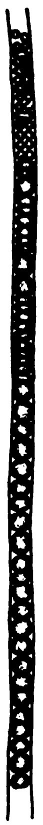


FIGURE 1.—Portion of a thread of *Crenothrix polyspora* showing formation of conidia. The lower part of the thread consists of ordinary vegetative cells. In the upper part are disk-shaped cells and conidia. Drawing with camera lucida. × 550.

The spores are nonmotile conidia. They are washed from the ends of the sheaths, distributed by currents of water, and eventually become attached and germinate into new threads. It often happens that conidia germinate before they have a chance to leave the sheath, and then the new threads push their way through the sheath, forming a radiating mass of threads which appear like branches of the old thread all coming out at one place. (See Pls. I, *A;* II, *A;* and III, *B.*) In many threads germination takes place at several points.

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[1] Rössler, O., Ueber Kultivierung von *Crenothrix polyspora* auf festem Nährboden: Archiv Pharmacie, Band 233, pp. 189–191, 1895.

[2] Molisch, Hans, Die Eisenbakterien, p. 29, Jena, 1910.

[3] Rullmann, W., Ueber Eisenbakterien: Centralbl. Bakteriologie, Abt. 2, Band 33, p. 283, 1912.

[4] The micron equals 0.001 millimeter.

Though the young *Crenothrix* threads are colorless, older threads are commonly coated with a thick brown deposit of ferric hydroxide, which frequently has a thickness of several times the diameter of the original threads. (See fig. 2.) Younger threads never have this coating and rarely show even a yellowish tint to indicate the presence of ferric hydroxide.

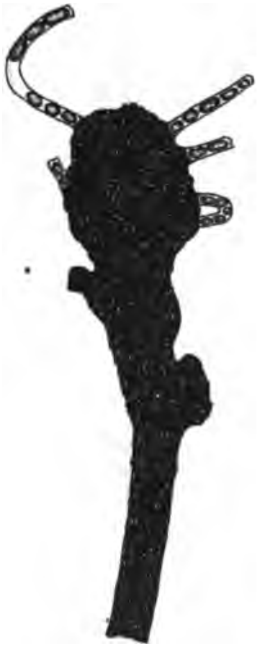


FIGURE 2.—Portion of a thread of *Crenothrix polyspora* showing thick coating of ferric hydroxide. Thin young threads are formed by germination of conidia in parent sheath. Drawing with camera lucida. × 1,080.

Crenothrix is readily stained with either carbol-fuchsin or gentian violet. The cells stain deeply, but the sheath remains almost colorless. When it is desirable to stain the spores the thread may be stained first with carbol-fuchsin and then treated with 2½ per cent glacial acetic acid. This will remove the stain from all parts of the thread except the spores. The mount may then be stained with gentian violet or methylene blue, which will restain the vegetative cells and also to some extent the sheath. The most satisfactory method of staining *Crenothrix* is to prepare a weak staining solution consisting of 1 part concentrated carbol-fuchsin to 10 parts of distilled water. The slide on which the organism is mounted should be allowed to remain in this solution for 12 or 14 hours. It is frequently advantageous to treat the material with a dilute solution of hydrochloric acid before staining.

LEPTOTHRIX OCHRACEA Kützing.

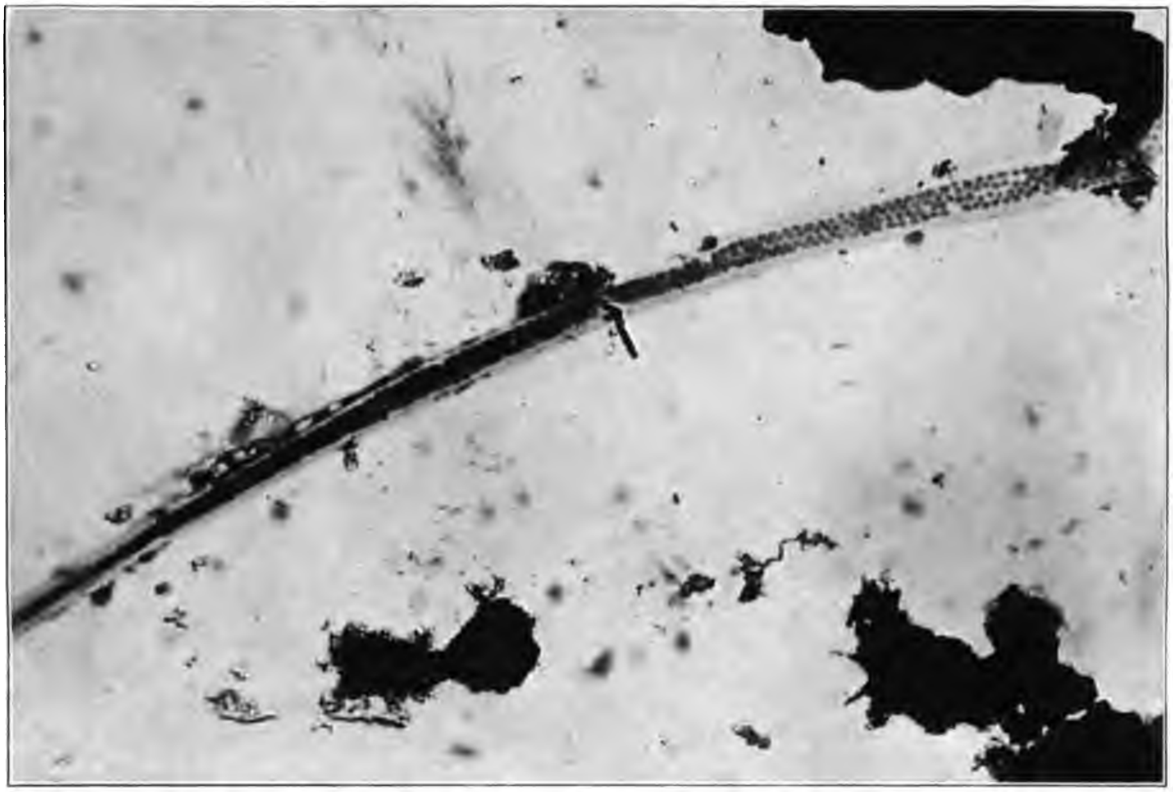
Leptothrix ochracea Kützing, also known as *Chlamydothrix ochracea* Migula, is found mainly in iron-bearing surface waters of bogs, streams, and springs, but I have found it also in mine waters in the Cuyuna iron range of central Minnesota and in the lead and zinc region of southwestern Wisconsin. In some iron springs *Lepothrix* is extremely abundant, but in others not even a trace of it can be found. This irregularity in its distribution is probably due to a difference in composition of the spring waters, perhaps influenced by other contributing factors. In streams and bogs it is found principally where the water is stagnant.

I found *Leptothrix* growing profusely in a chalybeate spring on a small creek west of Lake Kegonsa, about 14 miles southeast of Madison. (See Pl. IV.) The water of this spring contains an abundance of ferrous iron in solution and has a distinct iron taste. It issues from the hillside about 10 feet above the level of the creek, forming a little basin 2 or 3 feet in diameter. At the top of the slope at various points in the vicinity are outcrops of Madison sandstone (Lower Ordovician), and the water probably derives its iron from this formation either from disseminated pyrite or from siderite. The iron is probably present in solution as ferrous carbonate (or bicarbonate), judging from the following partial analysis, made by G. W. Crawford, of the University of Wisconsin:

Partial analysis of water from spring on creek west of Lake Kegonsa, Wis.

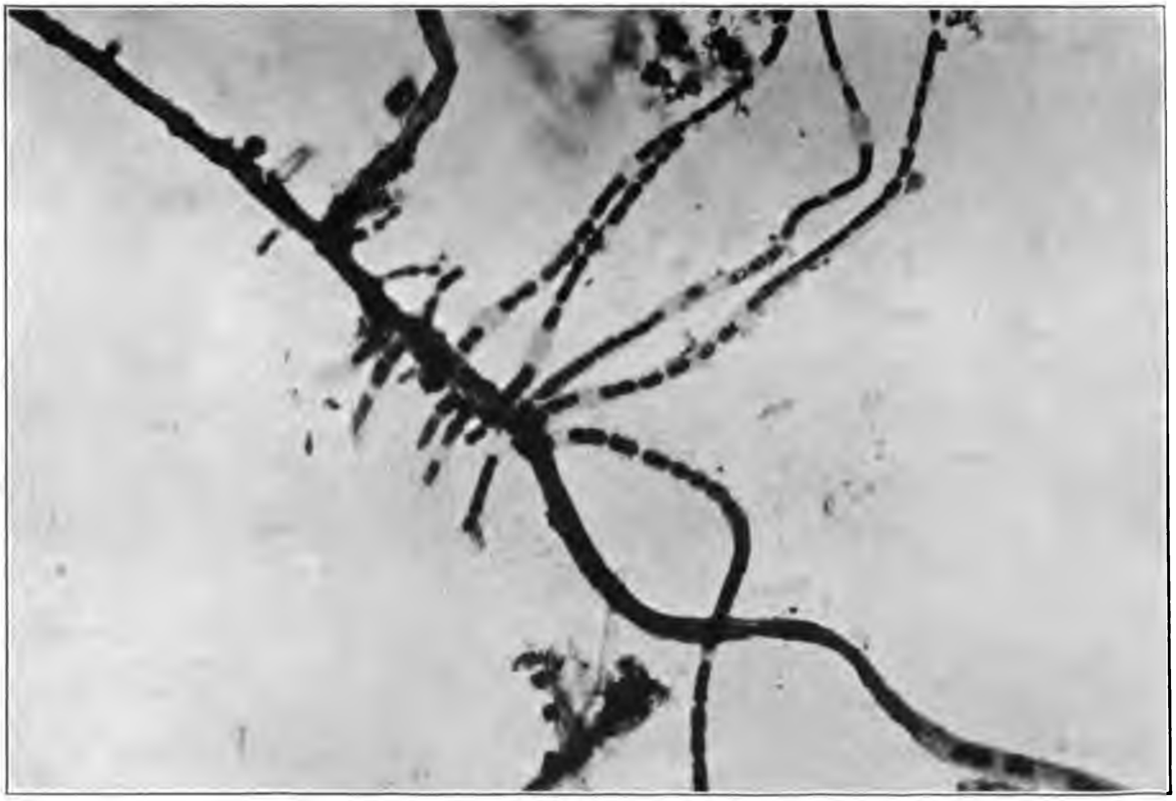
	Parts per million.
Silica (SiO_2)	18.9
Ferric oxide (Fe_2O_3)	5.2
Calcium (Ca)	78.1
Magnesium (Mg)	32.5
Bicarbonate radicle (HCO_3)	354.4
Sulphate radicle (SO_4)	.0
Chlorine (Cl)	.4
Free carbon dioxide (CO_2)	11.6

A large volume of water is given off by the spring and there is a constant flow winter and summer. The water does not freeze in the winter. As there is no sulphate radicle pres-



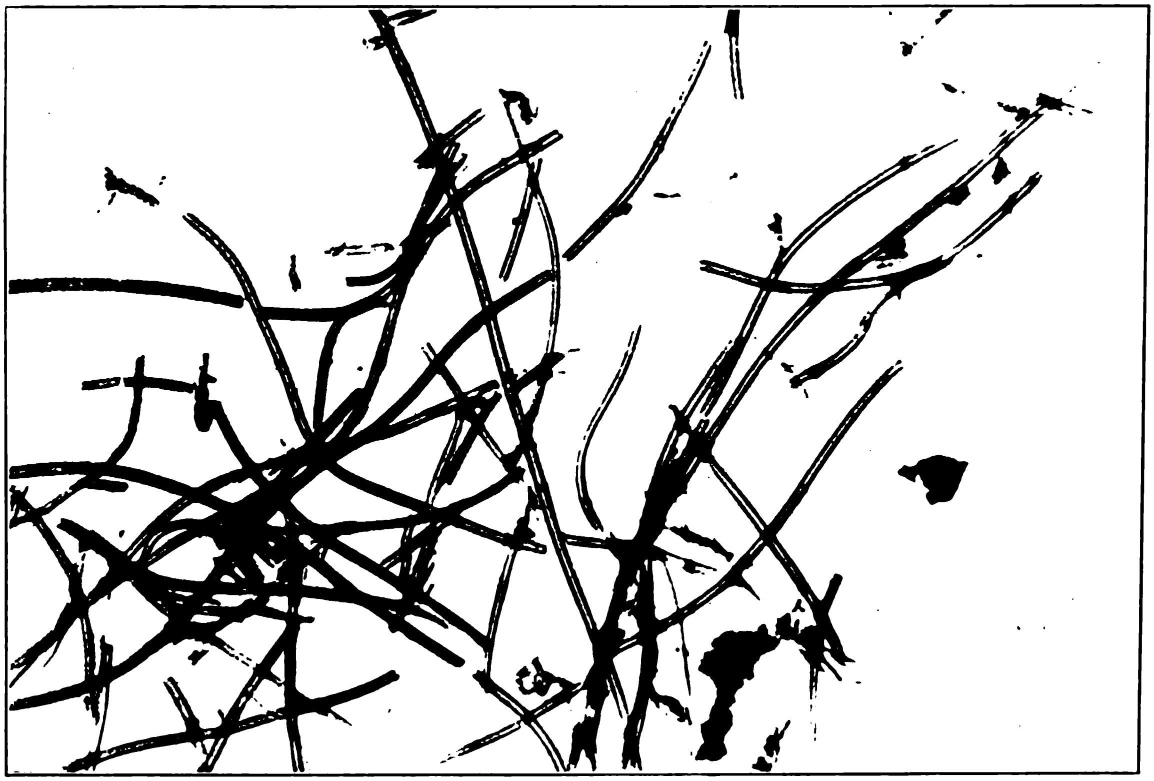
A. PHOTOMICROGRAPH OF THREAD OF CRENOTHRIX POLYSPORA FROM CITY WATER, MADISON, WIS., ×640.

Shows the formation of conidia from vegetative cells. Conidia occur in the upper part of the sheath (on the right) and vegetative cells in the lower part (on the left). Sheath is faintly outlined. Stained with gentian violet.



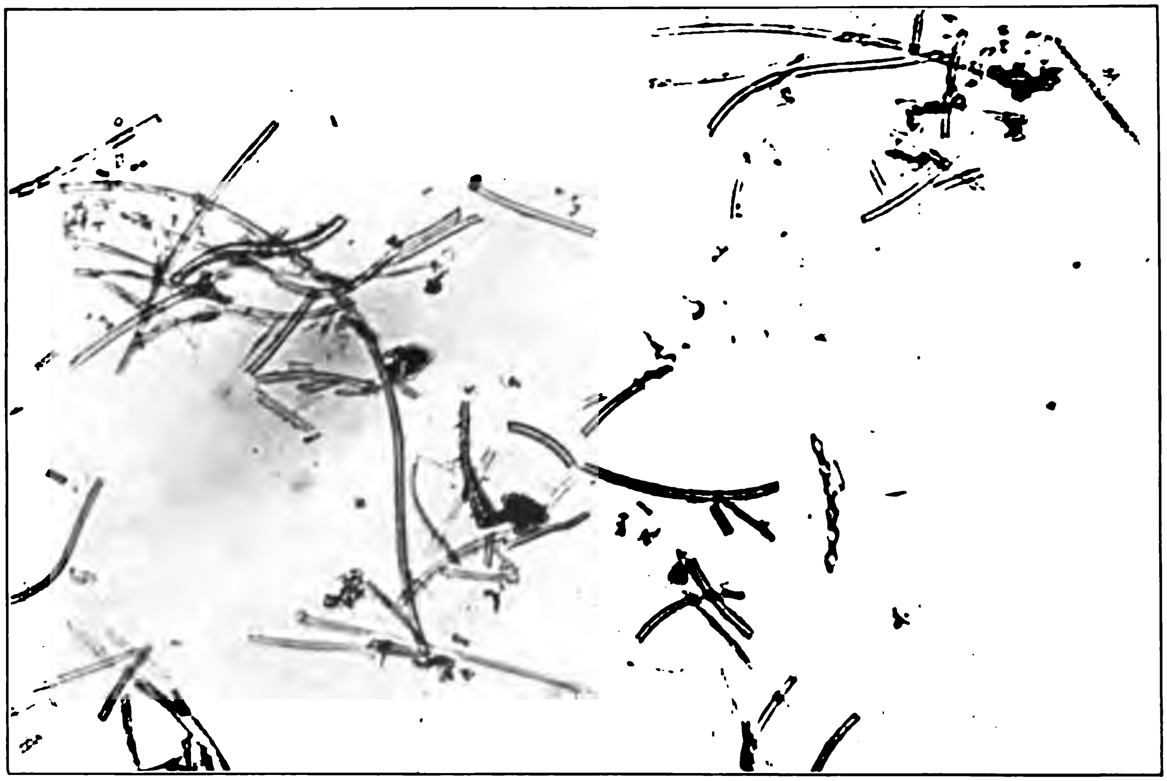
B. PHOTOMICROGRAPH OF THREAD OF CRENOTHRIX POLYSPORA FROM CITY WATER, MADISON, WIS., ×640.

Shows the germination of cells within the sheath. Sheath is also well shown in small threads. Stained with gentian violet.



A. PHOTOMICROGRAPH OF OCHEROUS SCUM IN IRON SPRING NEAR LAKE KEGONSA, MADISON, WIS., × 640.

Shows simple straight and curved threads of *Leptothrix ochracea*. Unstained.



B. PHOTOMICROGRAPH OF OCHEROUS SCUM IN IRON SPRING NEAR LAKE KEGONSA, MADISON, WIS., × 640.

Shows threads of *Leptothrix ochracea* and one of *Spirophyllum ferrugineum*. Thread of very regularly twisted *Spirophyllum* on the right. Unstained.

ent, and as the chlorine is negligible, it seems that in this spring at least all the calcium, magnesium, and iron are present in the form of carbonate (or bicarbonate). The iron, although given as ferric oxide in the analysis, is all present in the ferrous form, as is shown by the fact that the water as it issues from the spring is beautifully clear but upon standing soon becomes turbid on account of the oxidation of the iron by atmospheric oxygen. After a few days a distinct yellowish-brown deposit has formed at the bottom of vessels in which the water is kept and at the end of a week or two the iron is so completely precipitated that less than 0.2 part per million of ferric oxide remains in the solution, although the original content was 5.2 parts per million, as shown in the analysis. The 5.2 parts ferric oxide are equivalent to 3.69 parts metallic iron.

Leptothrix forms soft, fluffy brown botryoidal masses attached to the bottom and sides of the spring. The masses may be an inch or more in thickness and form a sort of lining locally along the sides and bottom of the spring. They consist of an almost pure culture of *Leptothrix* threads, both living and dead, but with these here and there are threads of *Spirophyllum*, all interwoven into a thick matting.

During the course of several visits to this spring I had an opportunity of noting the effect of seasonal changes on the growth of the iron bacteria. The most abundant growth apparently occurred in the spring and early in the summer; late in the fall the growth seemed to be at its lowest, being less marked even than in midwinter. During the period of lowest growth *Spirophyllum* seems to be somewhat more abundant relatively than during periods of luxuriant growth.

At the Rowe mine, an open-pit iron mine near Riverton, in the Cuyuna district in central Minnesota, a number of springs of iron-bearing water issue directly from the ore at the east end of the pit. The ore is a mixture of limonite and more or less hydrated hematite, but the water issuing from it probably contains ferrous iron in solution and supports an abundant growth of *Leptothrix* and various algae in little depressions on the surface of the ore.

In spring water from Middleburg, Va., procured for me by Dr. E. B. Fred, of the University of Wisconsin, I found *Leptothrix* occurring in abundance associated with some *Spirophyllum* and various types of algae. The spring is 1 mile northwest of Middleburg. The iron-bearing water issues from red clay probably derived by decomposition from Triassic red shale (Newark), outcrops of which occur within 50 feet of the spring. The waters flow into Wauquipin Creek, a tributary of Goose Creek, which empties into Potomac River 10 to 15 miles distant.

In the Kennedy mine, in the Cuyuna iron ore district, *Leptothrix* occurs abundantly on some of the lower levels. (See Pl. V.) On the 262-foot level two long crosscuts penetrate a succession of iron ore, ferruginous chert, cherty siderite rock, and green chloritic schist. The walls of these crosscuts, where they consist of cherty siderite rock and green schist and where water is abundant, support a luxuriant growth of *Leptothrix* associated with some *Spirophyllum* and *Gallionella.* Locally also pools of water on the floors of the crosscuts are filled with yellowish-brown to dark-brown masses of these organisms.

Microscopically the material is seen to consist very largely of *Leptothrix*, but here and there threads of *Gallionella* and *Spirophyllum* are common. Most of the *Leptothrix* threads are light yellowish-brown and transparent, but some are dark brown and have a thick irregular coating of ferric hydroxide. With careful handling very long threads of *Leptothrix* were obtained, some of which had a thick brown coating of ferric hydroxide at one end, though the other end was smooth and transparent, there being a gradation between the two ends. A few nearly colorless threads were seen which showed cell structure very plainly. Some of the cells were elongated cylindrical, some short cylindrical, and some were platelike. Whether these threads were really *Leptothrix* or whether they were some form of almost colorless algae or fungi it is not possible to say. In size and general form they were like *Leptothrix.* Other threads of *Leptothrix* occur which have little projections along them at intervals. These projections are probably little lumps of ferric hydroxide. but they resemble very closely the conidia described by Ellis in connection with the form for which Benecke[1] has suggested the name *Conidiothrix*.

A sample of the scum of iron oxide collected from the walls of the drifts of the Kennedy mine and dried at 105° C. was analyzed by W. G. Crawford, of the University of Wisconsin, with the following results:

Analysis of scum of iron oxide from Kennedy mine, Minn.

[Dried at 105° C.]

Ferric oxide (Fe_2O_3)	70.56
Silica (SiO_2)	7.27
Lime (CaO)	3.41
Magnesia (MgO)	.40
Combined water (H_2O)	13.75
Loss above 105° C. (besides combined water)	4.60
	99.99

This analysis shows that the material precipitated by the iron bacteria is practically pure ferric hydroxide, for the impurities may be attributed to small rock particles which were unavoidably included in the sample in collection. On the supposition that the iron is all present in the form of ferric hydroxide or limonite, 11.95 per cent of water is required to combine with 70.50 per cent of ferric oxide, making a total of 82.51 per cent limonite, or of 49.3 per cent metallic iron. This amount leaves 1.8 per cent of combined water unaccounted for, which probably means that the ferric oxide is in a slightly higher state of hydration than in the mineral limonite. The loss above 105° C., besides the combined water, is probably mainly carbon dioxide, derived from the oxidation of the carbon present in the bacterial sheaths. The silica, lime, and magnesia are accounted for by the presence of rock particles.

Besides finding *Leptothrix* in iron springs and mines I have found it in river waters and in bogs. In river waters I have found it especially common where pools of more or less stagnant waters occur along the banks between boulders or outcrops of rock. In some places it seems that these rocks yield iron for its growth.

In bogs ferric hydroxide frequently occurs as a thin iridescent film on the surface of the water. This film results from the oxidation of iron compounds in solution in the water. With such occurrences there is almost always associated a yellowish-brown scum or ooze along the sides and bottom of the pools of water. This scum generally consists of *Leptothrix* associated with more or less algae. It is well known that, on account of the abundant presence of decaying organic matter, bog waters can take a considerable amount of iron into solution. A thin layer of water near the surface, which is in direct contact with the oxygen of the air, probably suffers oxidation, and the iron in solution is changed to ferric hydroxide and forms the surface film. Below the surface it seems reasonable to suppose that the iron is kept in solution to some extent by products of decaying organic matter but that some of it is taken up by the iron bacteria and that ferric hydroxide is deposited on their sheaths. This material gradually accumulates and eventually forms deposits of bog iron ore.

On account of the abundant presence of ferric hydroxide in the sheaths, cultures of *Leptothrix* (and also of *Spirophyllum* and *Gallionella*) may be kept in water for an almost indefinite length of time for purposes of study. It seems that although the organisms die the sheaths retain their natural form.

Leptothrix ochracea has been grown in the laboratory by a number of investigators. The first laboratory cultures of *Leptothrix* were obtained by Winogradsky.[2] He used for the purpose a glass cylinder about 8 inches tall and placed in the bottom of this crushed hay which had been previously cooked. On this material he sprinkled some freshly precipitated ferric hydroxide and then filled the cylinder with well water. As soon as gas formation occurred, little ocher-colored flakes and masses appeared on the surface of the water and on the sides of the glass cylinder. In 8 or 10 days a thick, yellowish-brown deposit was found to cover the sides of the cylinder and on the surface of the water large zoogloea of the same color formed and gradually sank to the bottom. The ocher-colored masses were found to consist almost entirely of organisms, amorphous flocculent ferric hydroxide being very uncommon. Among these organisms *Leptothrix* was almost always present. The difficulty with this culture method was that be-

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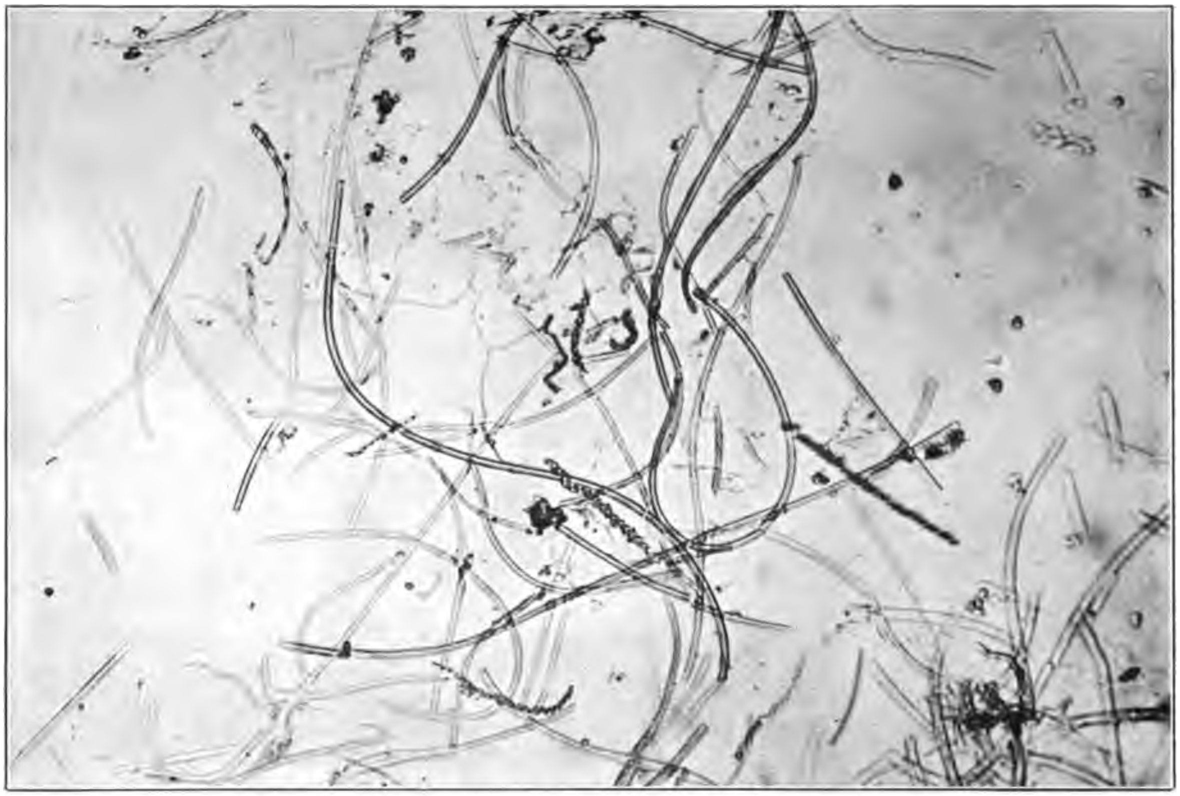
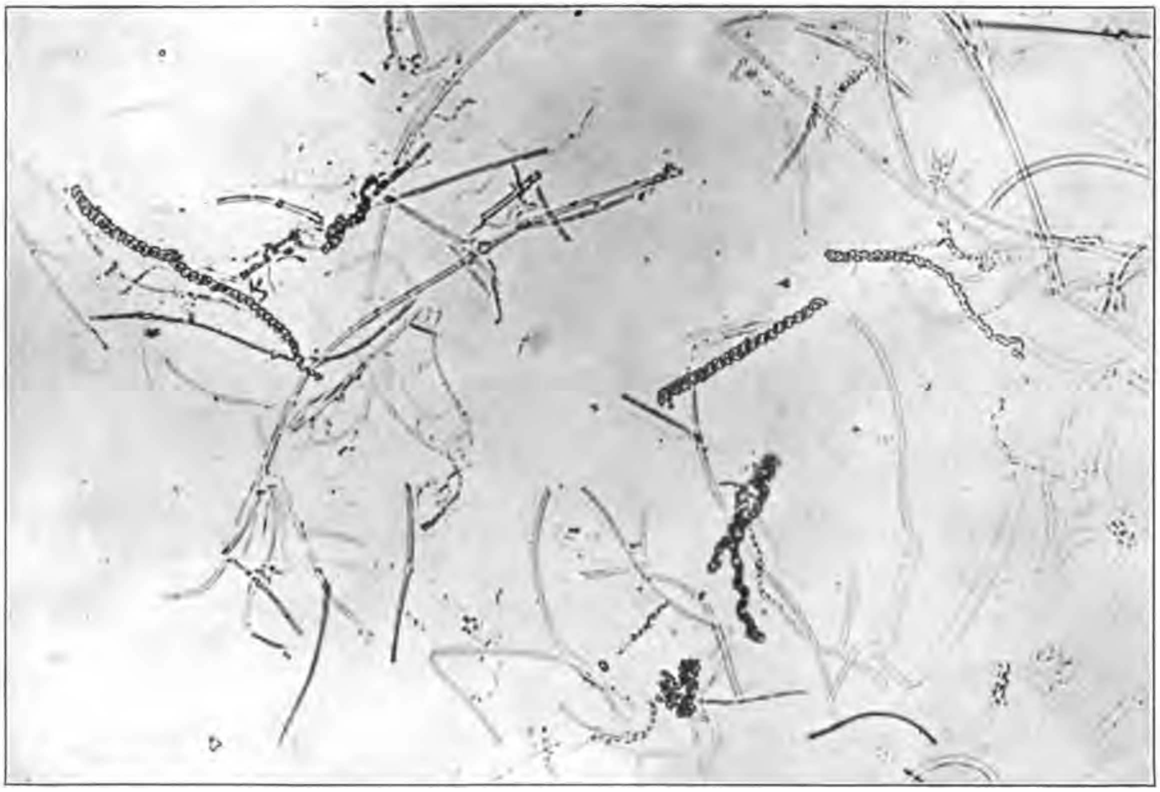
[1] Benecke, Wilhelm, Bau und Leben der Bakterien, 1912.

[2] Winogradsky, S., Ueber Eisenbakterien: Bot. Zeitung, Band 46, pp. 262–270, 1888.



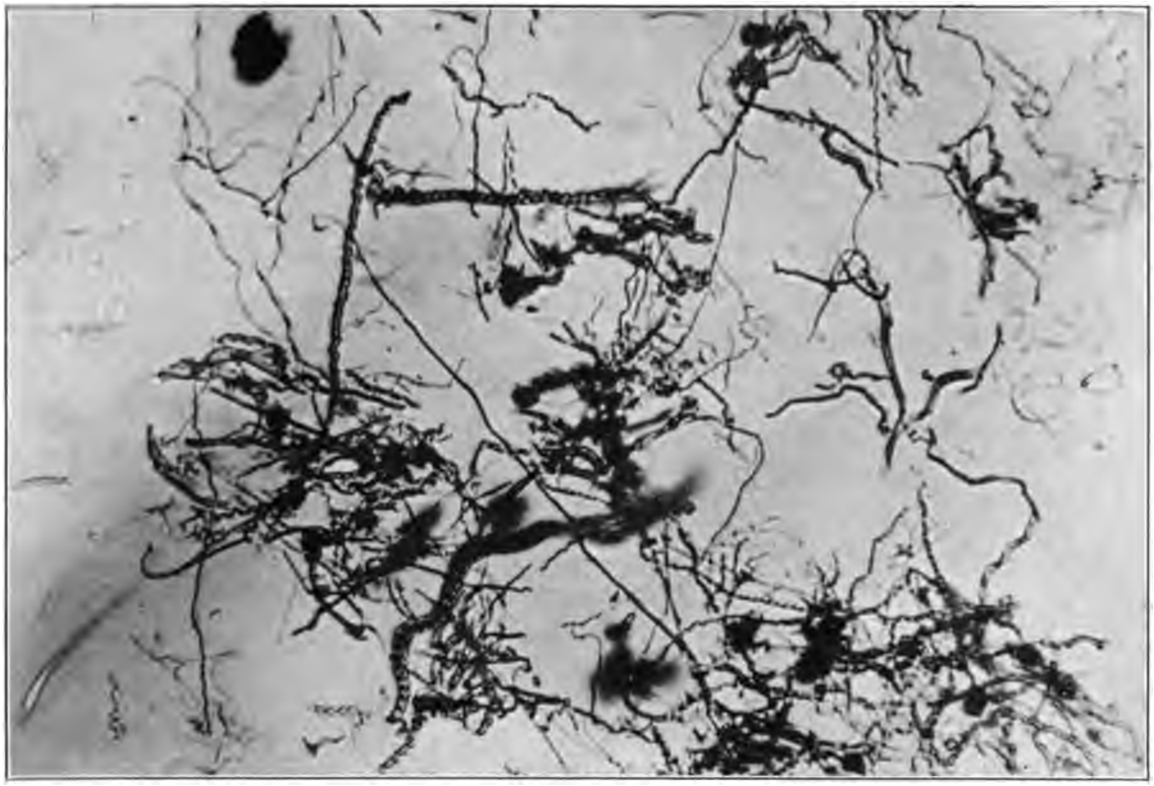
A. PHOTOMICROGRAPH OF MATERIAL FROM 262-FOOT LEVEL, KENNEDY MINE, CUYUNA, MINN., × 640.

Threads of *Spirophyllum ferrugineum* are near the upper left corner and near the center. Threads of *Leptothrix ochracea* and *Gallionella ferruginea* are scattered; the latter show braidlike forms. Unstained.



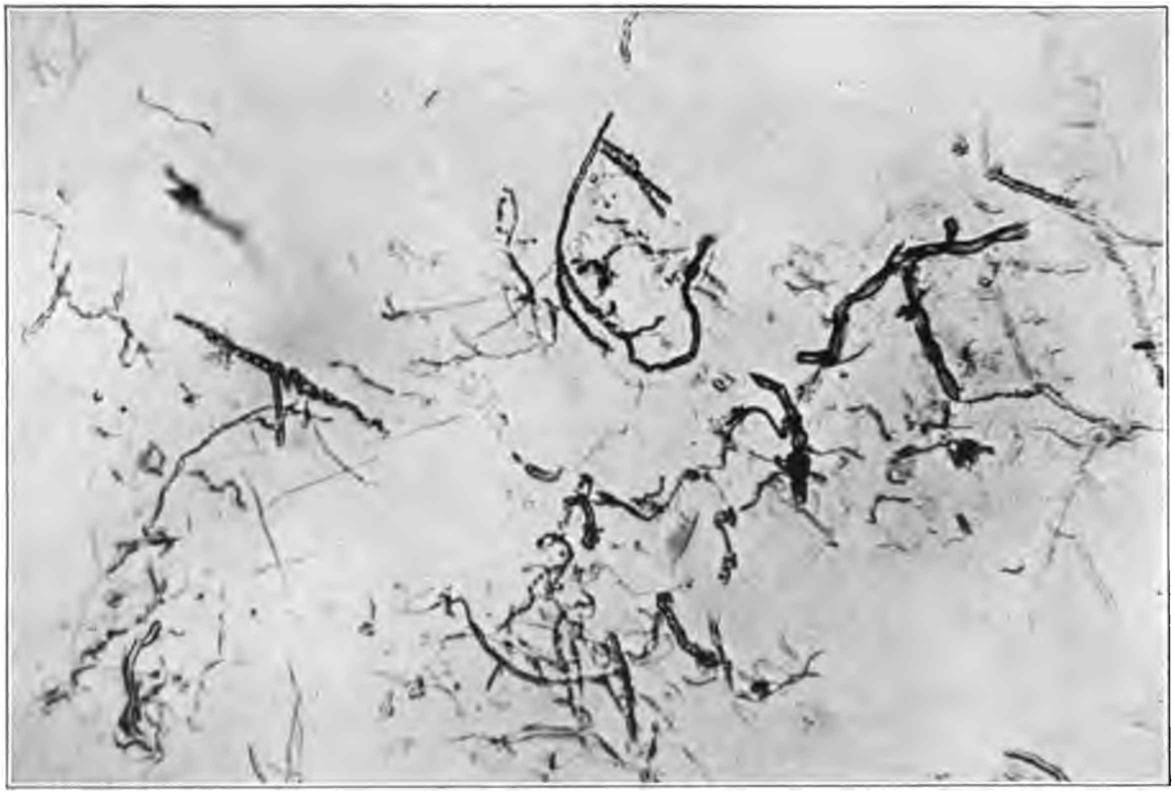
B. PHOTOMICROGRAPH OF OCHEROUS SCUM ON 262-FOOT LEVEL, KENNEDY MINE, CUYUNA, MINN., × 640.

Shows simple threads of *Leptothrix ochracea*, coiled, braidlike forms of *Gallionella ferruginea*, and a few spiral ribbon-like forms of *Spirophyllum ferrugineum*. Unstained.



A. PHOTOMICROGRAPH OF OCHEROUS, GELATINOUS SCUM FROM 100-FOOT LEVEL, FEDERAL MINE, HAZEL GREEN, WIS., ×640.

Shows braidlike forms of *Gallionella ferruginea* and also single spiral threads of *Gallionella ferruginea*. Twisted ribbon-like forms of *Spirophyllum ferrugineum* are abundant. Unstained.



B. PHOTOMICROGRAPH OF OCHEROUS, GELATINOUS SCUM FROM 100-FOOT LEVEL, FEDERAL MINE, HAZEL GREEN, WIS., ×640.

Shows ropelike forms of *Gallionella ferruginea*, one near the center consisting of four single threads; also single spiral threads of *Gallionella* and twisted ribbon-like forms of *Spirophyllum ferrugineum* of different sizes. Unstained.

sides *Leptothrix* numerous other bacteria as well as protozoa of many varieties developed, so that the culture was impure.

Adler[1] made some improvement by adding 0.05 per cent iron ammonium citrate to water from the city supply of Prague, which was taken from Moldau River, and allowing the solution to stand in a glass beaker. After some days yellowish flakes of *Leptothrix*, *Cladothrix*, and *Anthophysa* developed abundantly, as well as a few protozoa.

Molisch,[2] after many attempts, finally succeeded in getting pure cultures of *Leptothrix*. In an attempt to repeat Adler's experiments by using water from the city supply of Vienna, which was derived from springs, he was unsuccessful, and therefore he used water from Moldau River in all his experiments. His first experiments were for the purpose of obtaining an abundant growth of *Leptothrix* with the least possible development of other forms. He took various organic compounds of iron and manganese and dissolved them in water from Moldau River, in which *Leptothrix* was known to be present. The strength of the solutions used was usually about 0.05 per cent. The compounds with which he was most successful in obtaining growths of *Leptothrix* were manganpeptone, iron ammonium citrate, peptone with manganese carbonate, manganum phospholacticum, iron sulphide with peptone, and iron-ammonium tartrate. He found that in these solutions, which were kept in beakers in diffused light, little brown spots appeared near the surface in a few days and that after a week or two a thick matting formed over the surface. This was found to consist mainly of *Leptothrix*, but *Anthophysa* and *Cladothrix* were generally abundant, and other protozoa and algae also frequently developed.

Molisch then attempted the isolation of *Leptothrix* by growth on solid media. The medium which he found best adapted consisted of 1,000 cubic centimeters of water from Moldau River, 0.05 gram of manganpeptone, and 10 grams of agar. This medium was inoculated with *Leptothrix* which was obtained from impure cultures and was incubated at 25° C. In a few days, among numerous other bacterial colonies, certain light-brown colonies developed which soon became dark rusty brown and upon examination were found to consist entirely of *Leptothrix*.

Montfort[3] mentions the occurrence of heavy growths of *Leptothrix ochracea* in tanks containing moderately strong solutions of ferrous sulphate. He states also that the organism is easily grown in a 5 to 10 per cent solution of ferrous sulphate, and develops under such conditions in a few days. At my request Mr. Montfort sent me samples of the ferrous sulphate with which he had obtained cultures. However, I was unable to duplicate his results, although I made several attempts. The solutions gave an abundant yellowish-brown ocherous, flocculent precipitate, due to oxidation, which upon examination under the microscope gave no trace of any organic forms except occasional filaments of mold mycelium, some of which had a brown coating of ferric hydroxide. The precipitate consisted mainly of brownish-yellow mixed granular and flocculent material, probably partly basic ferric sulphate and partly ferric hydroxide.

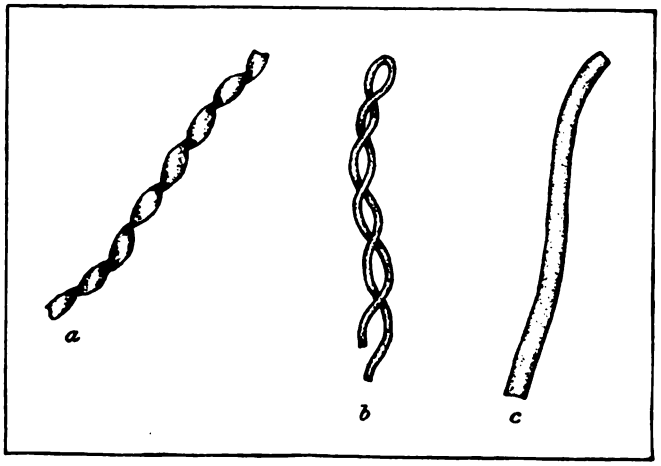


FIGURE 3.—Diagrammatic sketch of *Spirophyllum ferrugineum* (*a*), *Gallionella ferruginea* (*b*), and *Leptothrix ochracea* (*c*). Shows difference in size and structure of the organisms. × about 1,080.

Leptothrix ochracea (see Pls. IV and V and figs. 3, 4, 5, and 6) commonly occurs as un-

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[1] Adler, Oscar, Ueber Eisenbakterien und ihrer Beziehung zu den therapeutisch verwendeten natürlichen Eisenwässern: Centralbl. Bakteriologie, Abt. 2, Band 11, pp. 215–219, 277–278, 1903–4.

[2] Molisch, Hans, Die Eisenbakterien, Jena, 1910.

[3] Montfort, W. F., Dry feed of chemicals in water purification: Am. Waterworks Assoc. Jour., vol. 2, pp. 204–205, 1915.

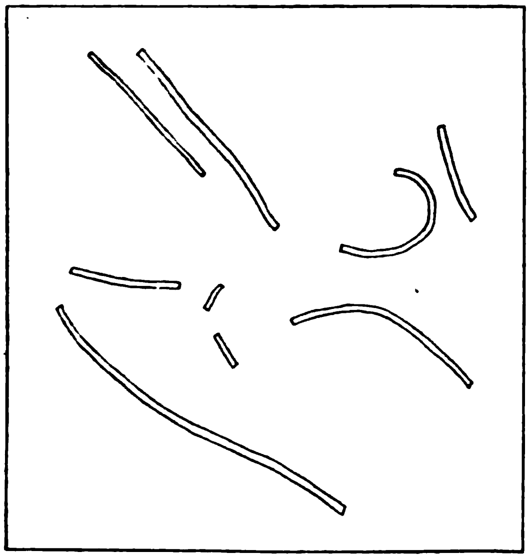

FIGURE 4.—Portions of threads of *Leptothrix ochracea* showing straight and curved forms. Drawing with camera lucida. × 550.

branched threads of the same width throughout and with usually no visible differentiation between the two ends. Ellis[1] described *Leptothrix* threads as being free at both ends and being held in place only because numerous threads intertwine with each other to form a thick matting which becomes attached to foreign objects. Benecke,[2] on the other hand, states that some of the threads are sessile and that then they show a thickening toward the attached end. *Chlamydothrix sideropus*, a related species, has a well-developed holdfast.[3]

Threads of *Leptothrix ochracea* almost invariably have a light yellowish-brown color, due to the presence of ferric hydroxide in the sheaths, which enables them to be studied without staining. They are very difficult to stain. I have tried staining with gentian violet, carbol fuchsin, and methylene blue, both with and without previous treatment with dilute hydrochloric acid, and the results have been very unsatisfactory. By careful treatment with dilute hydrochloric acid, however, and then staining for 10 or 12 hours in a dilute solution of carbol fuchsin, I have succeeded in staining the sheaths, but I have not been able by any method to bring out clearly the cell structure.

The average width of the threads of *Leptothrix* is about 1½ micra, but they range in width from 1 micron to 2 micra. The longest thread that I have noted measured about 120 micra, or about one-eighth of a millimeter, but doubtless the threads grow to a much greater length, being broken during the manipulations necessary for microscopic examination. Generally the threads are slightly curved or undulatory, but some short threads are quite straight. Rarely *Leptothrix* may be twisted spirally into a corkscrew form.

In fresh cultures of *Leptothrix* I have occasionally seen threads that show a differentiation into cells. The cells are usually long cylindrical in shape with slightly rounded ends. They vary greatly in length, but generally the length is many times the width. By far the greater mass of threads in ordinary cultures, however, shows no cell structure whatever, which may be due to the cells being obscured by the ferric hydroxide that colors the sheath or to the sheaths being empty. Molisch[4] states that by treatment of the threads with a 2 to 5 per cent solution of hydrochloric acid he was able to dissolve the ferric hydroxide from the sheath and thus brought out very plainly the

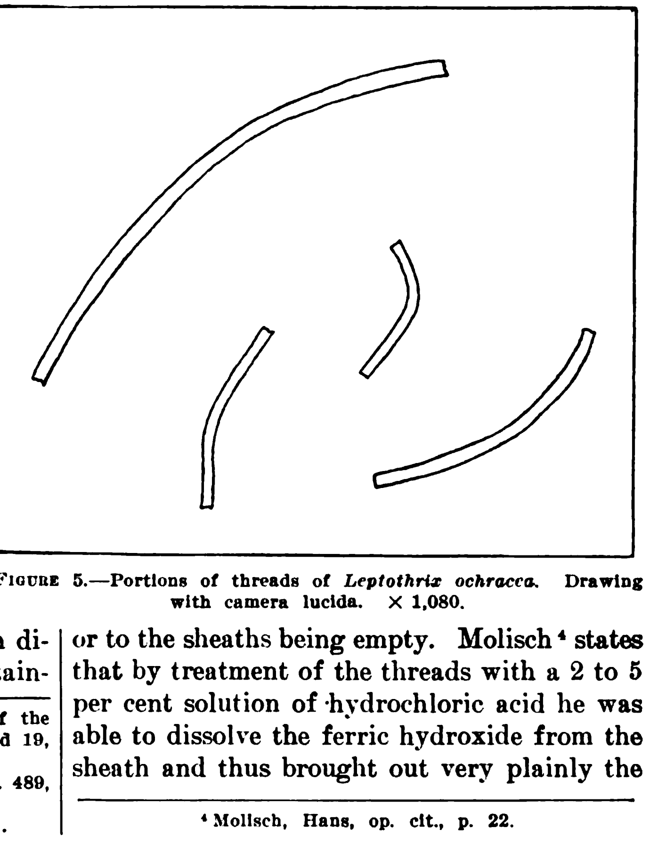

FIGURE 5.—Portions of threads of *Leptothrix ochracea*. Drawing with camera lucida. × 1,080.

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[1] Ellis, David, A contribution to our knowledge of the thread bacteria: Centralbl. Bakteriologie, Abt. 2, Band 19, pp. 503–505, 1907.

[2] Benecke, Wilhelm, Bau und Leben der Bakterien, p. 489, 1912.

[3] Molisch, Hans, Die Eisenbakterien, pp. 14–16, 1911.

[4] Molisch, Hans, op. cit., p. 22.

cell structure in threads that under ordinary conditions showed no cell structure whatever. I have attempted this with many cultures but without success, perhaps because the cultures used were too old.

Leptothrix ochracea is said by Molisch[1] to reproduce in three ways—by fragmentation (that is, by the breaking off of small fragments of threads which in time grow into new threads), by the forcing out of end cells from the thread, and by swarm cells. The swarm cells are cylindrical rods with rounded ends 0.6 to 0.8 micron in width and attain a maximum length of 14 micra. Some of them are threadlike and consist of several cells. Their movement is backward and forward, as well as rotational around the longer axis. The swarm cells after they leave the cell swim around and finally attach themselves and form new threads. Frequently they attach themselves to old threads and thus simulate branching forms. Swarm cells are said to stain readily with aniline dyes.

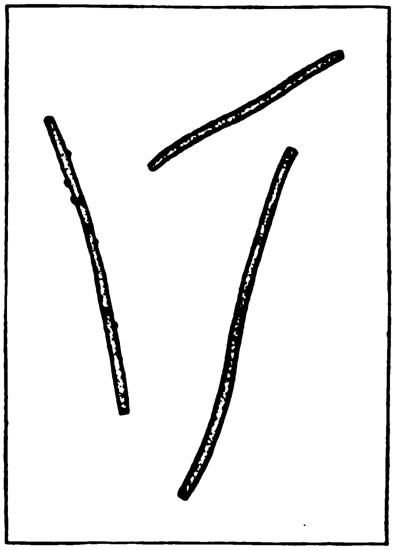

FIGURE 6.—Portions of threads of *Leptothrix ochracea*, one of them showing nodular projections. Drawing with camera lucida. × 1,080.

Ellis,[2] in his descriptions of *Leptothrix*, states that it reproduces by the formation of conidia. He described *Leptothrix* as a simple thread, straight or curved, which shows no cell structure. The conidia form small spherical projections on the sides of the threads and gradually detach themselves and are carried away by currents to other places, where they germinate and produce new threads. According to Ellis, this is the common mode of reproduction for *Leptothrix*. Molisch, however, states that he has never seen these conidia and doubts their existence, believing that the projections observed by Ellis may have been lower bacteria which have attached themselves to the *Leptothrix* threads, or that perhaps they were swarm cells of *Leptothrix* itself. Benecke,[3] in reviewing the facts, suggests that the form described by Ellis may be a new species related to *Gallionella*, and proposes the term *Conidiothrix* for it if such a form is proved to exist by further investigations.

In several of the cultures which I have collected recently, notably a culture of *Spirophyllum* and *Gallionella*, from the 100-foot level of the Federal mine, near Hazel Green, in southwestern Wisconsin, I have found a form resembling that described by Ellis. It consists of a thread similar to *Leptothrix* in size and general form. (See Pl. VII, *A*, and fig. 6.) However, no threads were found which gave any semblance of cell structure, but many threads showed small, rounded projections at irregular intervals along the thread. Whether these projections were attached particles of ferric hydroxide or other foreign material, or whether they were really conidia, was difficult to determine. They seemed, however, to be part of the thread, not having any distinct partition wall separating them from the thread. It is also rather significant that in only a few out of many cultures of *Leptothrix* which I examined have I found these forms. On the other hand, many of the cultures contain threads of *Leptothrix*, some of them thickly coated with ferric hydroxide, which show little projections and irregularities, consisting, without much doubt, of ferric hydroxide. It is therefore difficult to say whether the form mentioned above is the same as that described by Ellis as *Leptothrix* or whether all the projections are simply foreign bodies, as is suggested by Molisch. I have never found these bodies in a germinating condition, nor have I found them where they have been completely separated from the parent thread by abstriction.

In view of the fact that some investigators, such as Molisch and Benecke, describe *Lepto-*

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[1] Molisch, Hans, op. cit., p. 43.

[2] Ellis, David, op. cit.

[3] Benecke, Wilhelm, op. cit.

thrix as having well-developed cell structure, whereas others, such as Ellis, have not been able to find any evidence of cell structure, there is some question as to whether there may not exist two similar forms both widely distributed, the one showing cell structure and the other consisting of simple undifferentiated threads resembling those of *Gallionella* and *Spirophyllum.* Careful work is necessary not only to determine whether the latter form exists, but if so, whether it reproduces by the external abstriction of conidia or simply by the breaking off of parts of the threads. The method of reproduction has to be definitely determined for *Spirophyllum* and *Gallionella* as well.

GALLIONELLA FERRUGINEA Ehrenberg.

The term *Gallionella* was applied by Ehrenberg[1] in 1836 to all the organisms which are concerned in the formation of the brown iron scums of bogs and springs. That the brown scum at the bottom of certain wells was composed of organisms was also recognized by him and these organisms are mentioned as being a related type. He classified the iron organisms as infusoria and thought that they were related to the diatoms, which he had studied and which he also believed to be infusoria. Thus iron bacteria were at one time classed as unicellular animals, but later it was recognized that they were really plants and for some time they were grouped with the algae. Gradually as the investigations progressed it was determined that more than one species of iron bacteria were concerned in the formation of iron scums, and thus *Leptothrix*, *Crenothrix*, and more recently *Spirophyllum* and *Clonothrix* were recognized as distinct types. At present the term *Gallionella* is restricted to the ropelike form that consists of double spirally twisted threads.

Up to the present time I have found *Gallionella* in only three localities, namely, in the Federal mine, near Hazel Green, in southwestern Wisconsin, where it occurs in great abundance in association with *Spirophyllum;* in the Kennedy mine, in central Minnesota, where it is found in minor amount with predominating *Leptothrix* and some *Spirophyllum;* and in the filtrate from water from the city supply of Madison, Wis., where it is associated with *Spirophyllum* and *Crenothrix.*

The material in the Federal mine and the Kennedy mine occurs in brown gelatinous masses, which are attached to the walls of the tunnels beneath small openings from which streams of iron-bearing water issue, and which is also found in pools along the floors of the drifts.

The cultures from the Federal mine (see Pls. VI and VII, *A*), when examined microscopically, were found to contain abundant *Gallionella* of various forms and sizes. Perhaps the most common form is a short twisted ropelike thread consisting either of two or four single threads closely twisted together. The twisting is accomplished by the bending of single threads in the middle and twisting the ends around each other. There are also present very loosely twisted forms and single spiral or corkscrew-like threads, resembling a single strand from a rope when untwisted. The ropelike forms of *Gallionella* vary considerably in width from end to end, the thick end being usually that where the loose ends of the threads project. Different individuals also vary in width and length, not only among the ropelike forms but also among the single threads, which show a considerable range in size.

In the cultures from the Kennedy mine (see Pl. V) *Gallionella* is not very abundant, and most of it has the ropelike form. Many individuals are quite thin and transparent, not much thicker than the associated *Leptothrix* threads, whereas others are thick and heavily coated with brown ferric hydroxide. Some show the free ends of the separate threads projecting at one end, but most of them are short thick braids. Some have the same width throughout, but others taper toward one end.

Spirophyllum, *Gallionella*, and *Crenothrix* occur together in the distributing pipes of the water system of Madison, Wis. Upon filtering with a porcelain filter a dark-brown mud is frequently obtained, especially when the water is turbid. Upon examination with a microscope this mud is seen to consist largely of flocculent textureless masses of ferric hydroxide with scattered strands of *Spirophyllum* and *Gallionella* and here and there short pieces of *Crenothrix* threads. The *Crenothrix*

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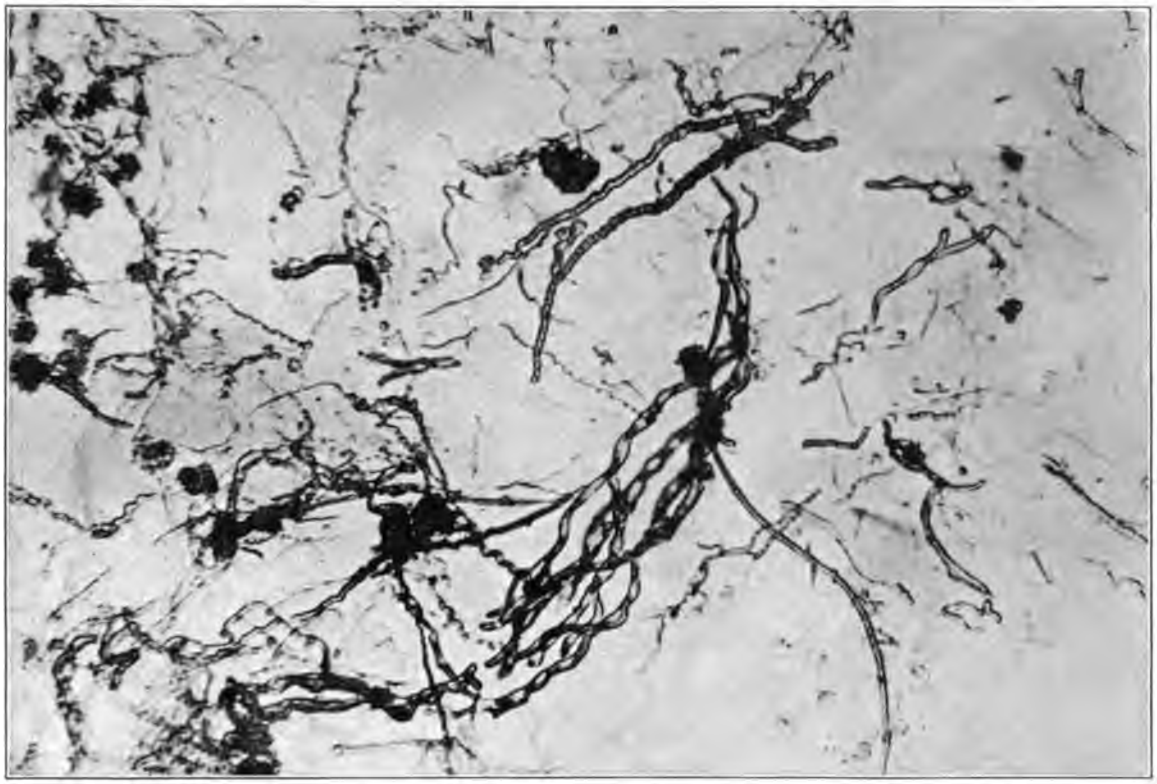
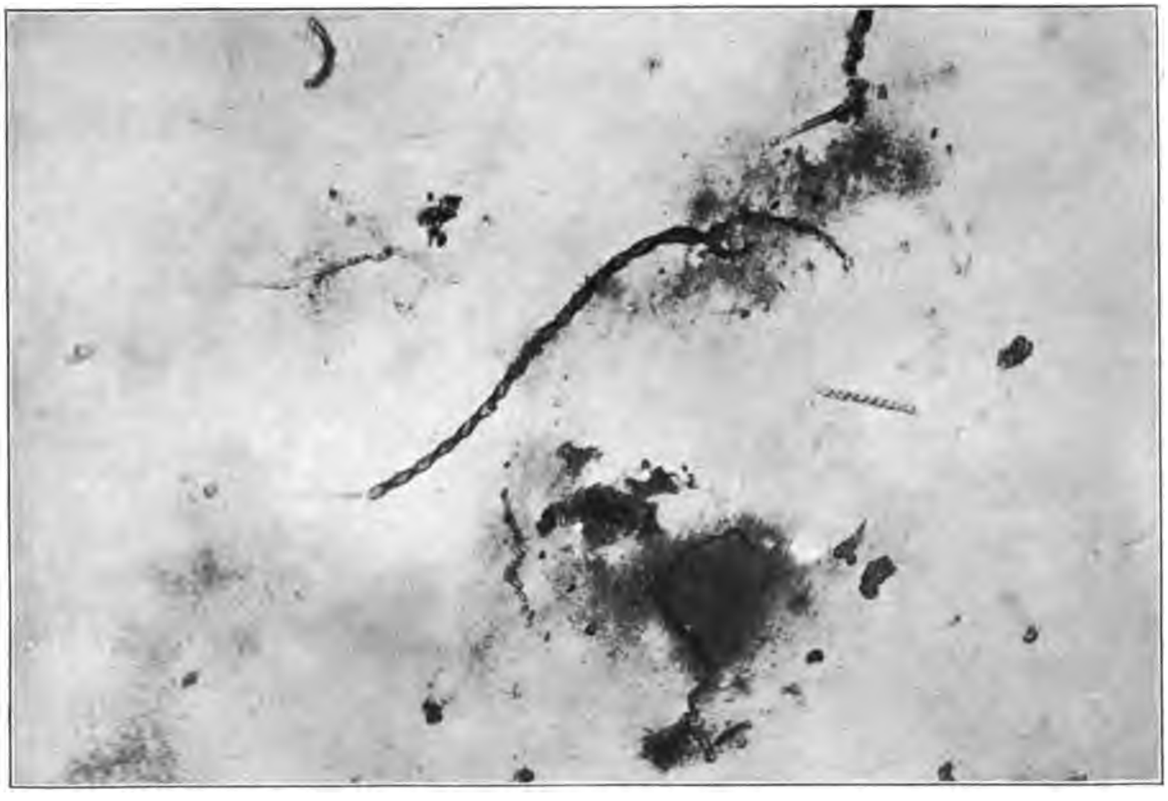
[1] Ehrenberg, C. G., Vorläufige Mittheilungen ueber das wirklige Vorkommen fossiler Infusorien und ihre grosse Verbreitung: Poggendorf's Annalen, Band 38, pp. 213–227, 1836.



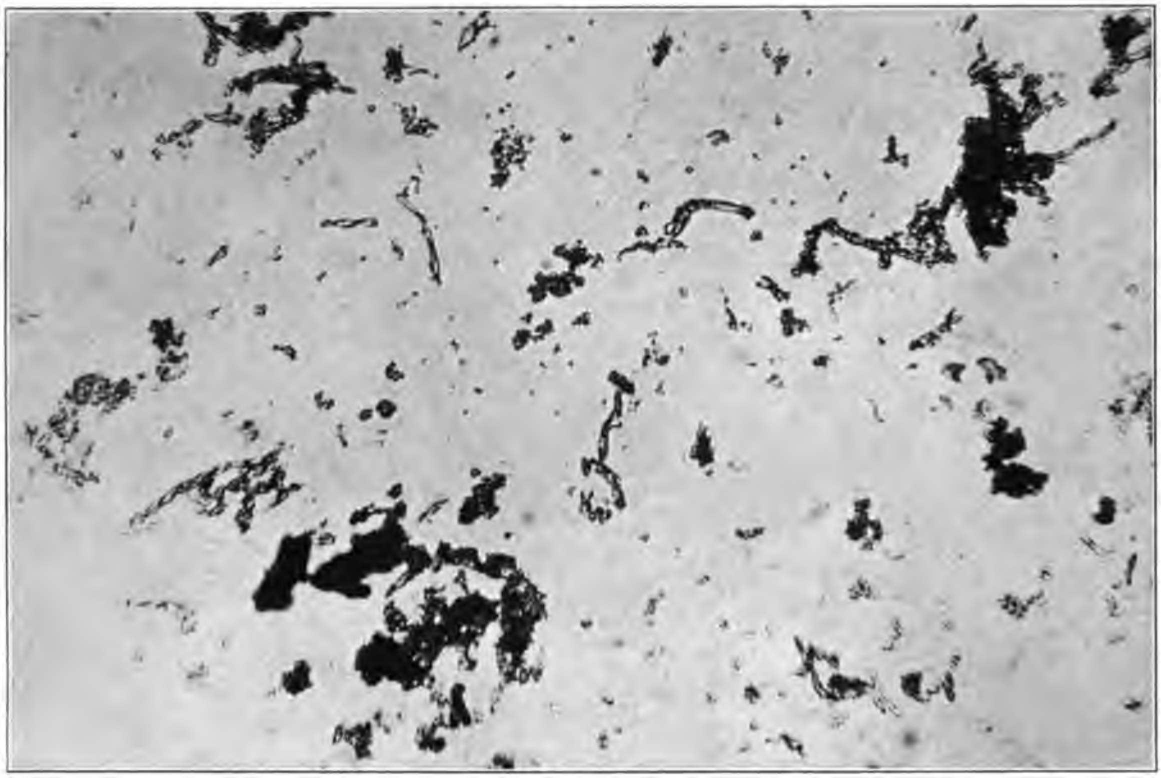
A. PHOTOMICROGRAPH OF OCHEROUS, GELATINOUS SCUM FROM 100-FOOT LEVEL, FEDERAL MINE, HAZEL GREEN, WIS., × 640.

Shows irregularly twisted ribbon-like forms of *Spirophyllum ferrugineum*, a few braidlike forms of *Gallionella ferruginea*, and a thread of *Leptothrix ochracea* with nodular projections. On the right is a double form of *Spirophyllum*. Unstained.



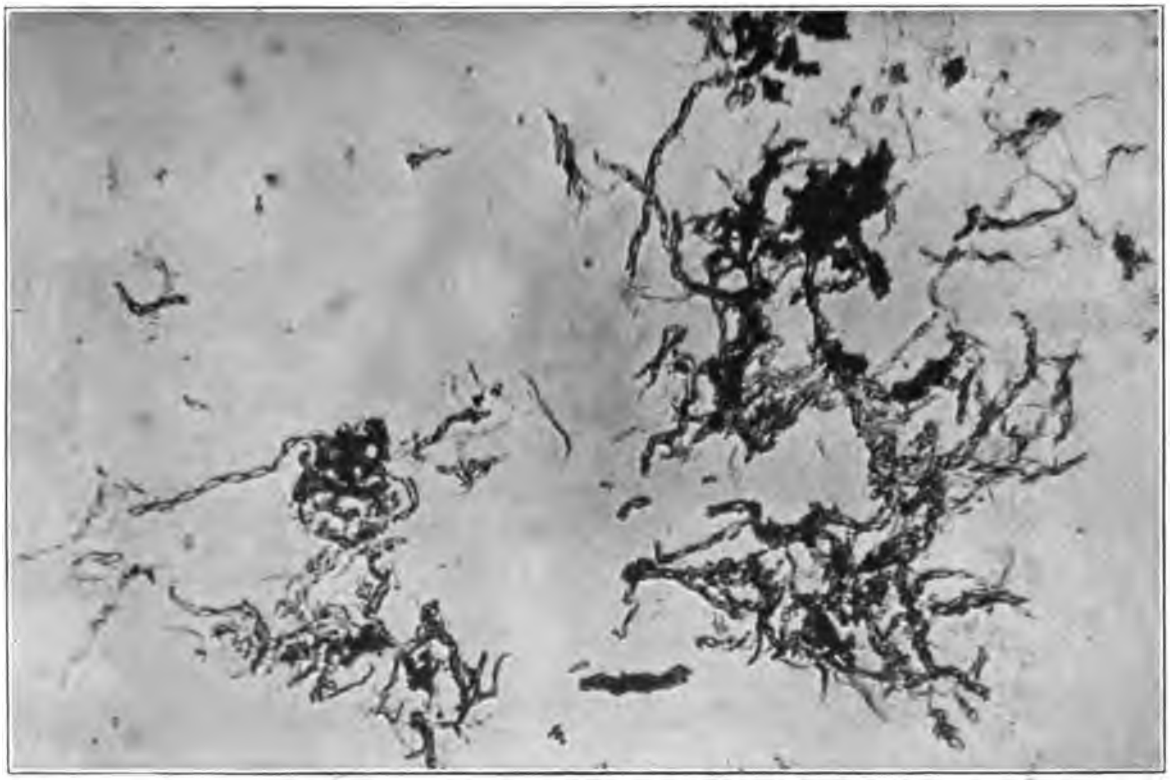
B. PHOTOMICROGRAPH OF DOUBLE TWISTED RIBBON-LIKE FORM OF SPIROPHYLLUM FERRUGINEUM FROM CITY WATER, MADISON, WIS., × 640.

The dark masses are gelatinous ferric hydroxide. Unstained.



A. PHOTOMICROGRAPH OF OCHEROUS SCUM FROM 300-FOOT LEVEL, JUDSON MINE, ALPHA, MICH., ×640.

Short twisted ribbon-like forms of *Spirophyllum ferrugineum* mixed with irregular masses and scattered specks of granular and gelatinous ferric hydroxide. Some *Spirophyllum* is coated with granules of ferric hydroxide. On the left is a double twisted form. Unstained.



B. PHOTOMICROGRAPH OF OCHEROUS SCUM FROM 200-FOOT LEVEL, JUDSON MINE, ALPHA, MICH., ×640.

Shows numerous small, irregularly twisted forms of *Spirophyllum ferrugineum*. Near the bottom is a short form thickly coated with granular ferric hydroxide. The dark irregular masses are gelatinous ferric hydroxide. Unstained.

will grow and develop into long threads when placed in culture media, as previously described, but apparently no growth of *Spirophyllum* and *Gallionella* takes place on the filter.

Water pipes in cities where the water contains an appreciable amount of iron in solution are a common habitat of *Gallionella*, *Spirophyllum*, and *Crenothrix*. In some places the precipitation of ferric hydroxide by the iron bacteria is so abundant that crusts are formed around the inside of the distributing pipes. These crusts increase in thickness until they completely fill the pipes and block the passage of the water. The material composing the crusts has been examined and has been found to contain large numbers of bacterial casts, so that little doubt exists as to its origin.

It is claimed by some investigators that the growth of *Crenothrix* and associated iron bacteria in city water pipes is not dependent on the original iron content of the water but is due to iron taken into solution from the pipes, and that the most abundant growth takes place in newly laid pipes. Doubtless the solution of iron from distributing pipes is a contributing factor, yet it seems evident that some iron must be in solution originally or iron bacteria would be found in all city waters and not confined to certain localities, in most of which the water is known to have a high original iron content. I have tried to find *Crenothrix* and other iron bacteria in distributing pipes where the water was obtained from lakes and had a low iron content but have been unsuccessful.

Schorler,[1] while examining some iron crusts from pipes from the city of Dresden, found that pipes which were thickly encrusted on the inside with iron oxide and which had been in use for 30 years had suffered no corrosion on the inside underneath the iron crust. This condition he thought indicated that the iron forming the incrustation came from some source other than the pipes themselves and that the deposition on the walls occurred through the medium of iron bacteria, which here found a favorable place for growth. In this locality Schorler found that the organism responsible for the precipitation was principally *Gallionella*, casts of which he found to be abundant in the iron crust.

Gallionella ferruginea may be likened to a hairpin the two ends of which have been twisted around each other. (See figs. 3, 7, and 8, and Pls. V, VI, and VII, *A*.) Sometimes such a twisted form may be bent again in the middle and the two ends be twisted around each other, thus forming a rope of four single strands. (See Pl. VI, *B*.) In some individuals the twisting is very loose, in others close. (See figs. 7 and 8.) I have found different coiled forms to range in width from 1 to 3½ micra. In individual coils the difference in width between the two ends may be as much as 1 micron. The longest coiled form that I have observed was about one-fourteenth millimeter in length, or 70 micra.

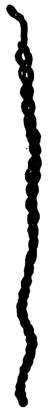


FIGURE 7.—Loosely twisted, ropelike form of *Gallionella ferruginea*. Drawing with camera lucida. × 1,080.

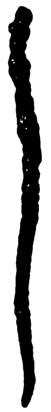


FIGURE 8.—Closely twisted, ropelike form of *Gallionella ferruginea*. Drawing with camera lucida. × 1,080.

The single threads which compose these ropes or coils are very thin and have the same width throughout, although different individuals vary in size. The common range is from less than 0.5 to about 0.75 micron. The longest single thread I have noticed was about 0.05 millimeter in length. Most of the single threads which occur are probably detached parts of coils, for they generally show the spiral form. As in *Spirophyllum*, no differentiation has ever been noticed between the two ends of the threads of *Gallionella*, nor has any cell structure ever been distinguished. The organisms appear to be simple threads.

Gallionella has a yellowish-brown to brown color. The ropelike forms are quite dark brown, much darker than similar forms of *Spirophyllum*.

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[1] Schorler, B., Die Rostbildungen in den Wasserleitungsröhren: Centralbl. Bakteriologie, Abt. 2, Band 15, pp. 564–568, 1906.

The methods of reproduction of *Gallionella* have not been thoroughly studied. Migula[1] describes the reproduction as taking place by the breaking off of parts of the threads, these being carried away by water currents to other localities and growing into new threads. Ellis[2] claims that in addition to the above method of reproduction *Gallionella* also multiplies by the external abstriction of conidia similar to *Spirophyllum* and the form which he describes as *Leptothrix*. In connection with *Gallionella* and *Spirophyllum* he describes the formation of abundant little projections all over the surface of the threads. In some individuals their development is so profuse as to almost conceal the parent thread. These little projections after becoming separated from the thread are said to germinate and form new threads. I have frequently seen *Gallionella* and especially *Spirophyllum* covered with small light-brown spherical or somewhat irregular bodies of fairly uniform size such as Ellis describes but have never become convinced as to whether they are conidia or particles of ferric hydroxide. Upon treatment with hydrochloric acid they disappear, as they would if they consisted of ferric hydroxide, yet it is true also that the entire thread is destroyed in a very short time by similar treatment.

Schorler,[3] in connection with his investigations on the formation of crusts of iron rust by *Gallionella* in the city water pipes of Dresden, found numerous strands of *Gallionella* in the outer portion of the crust, whereas the older interior portion of the crust consisted of a structureless mass of ferric hydroxide. He found that the individual strands of *Gallionella* had granular coatings of ferric hydroxide, which increased in thickness with the age of the strand and gradually caused its structure to disappear. He describes the development of small hexagonal crystals of hydrated ferric oxide on the sides of the older threads and states that they gradually increase in size and incorporate within them the surrounding granules of ferric hydroxide. Their growth results in the gradual disappearance of the strands and the development of the textureless ferric hydroxide mass typical of the older portion of the crust.

From this and other descriptions it appears that various investigators have noticed the formation of granules and projections on *Gallionella* and *Spirophyllum* threads, but only Ellis has connected them with the formation of conidia.

SPIROPHYLLUM FERRUGINEUM Ellis.

Spirophyllum ferrugineum Ellis appears to be the most widespread of the iron bacteria. It occurs abundantly in iron-bearing surface waters, as well as in underground waters. It is almost always associated in greater or less abundance with other iron-depositing thread bacteria and frequently occurs where other iron-depositing thread bacteria are absent. With *Leptothrix* it is found in springs and clear stream waters, even where *Leptothrix* grows very profusely. With *Crenothrix* and *Gallionella* it is found in city water systems, and with *Gallionella* or *Leptothrix* it is found in mine waters. In some iron springs and mines almost pure cultures of *Spirophyllum* occur, *Leptothrix* and *Gallionella* being entirely absent.

I first encountered *Spirophyllum* abundantly in cultures obtained from the Federal mine, a zinc mine located near Hazel Green, in southwestern Wisconsin. (See Pls. VI and VII, *A*.) The mine workings are in the lower part of the Galena limestone, and zinc, lead, and iron sulphides occur with calcite in veins in the limestone.

Waters issue from fissures and openings at numerous points in the mine. Where the culture was obtained a little stream of iron-bearing water issued from a small fissure in the rock wall a short distance below a horizontal vein containing sphalerite, marcasite, and calcite. Below the opening, attached to the rock wall and forming a streak to the floor, was a soft gelatinous brown deposit of ferric hydroxide which had a maximum thickness of one-half inch and a maximum width of 2 inches. A short distance from this point a basin in the rock floor was filled with water and contained a thick brown deposit of ferric hydroxide. The material forming the streak beneath the fissure opening upon examination proved to consist largely of *Spirophyllum* and *Gallionella*, with some *Leptothrix* or perhaps *Conidiothrix*. (See pp. 17–18.) Various forms of *Spirophyllum* were present, the most common being a wide, irregular, loosely twisted form. (See Pl. VI.) Other types are very regularly twisted and have the appearance of strings of beads. Their variation in size is considerable, some being almost as narrow as a single thread of *Gallionella*, whereas others are as wide as rope forms of *Gallionella*. Both single and double threads occur.

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[1] Migula, W., System der Bakterien, Band 2, p. 1031, 1900.

[2] Ellis, David, op. cit., pp. 505–507.

[3] Schorler, B., op. cit.

Subsequently I obtained almost pure cultures of *Spirophyllum* on the 200 and 300 foot levels of the Judson mine, south of Crystal Falls, Mich. (See Pl. VIII.) This mine is located on a steeply dipping deposit of red hematite inclosed in slate walls. The footwall consists of dark-gray pyritic slates. Water issues from numerous small fissures throughout the mine and yellowish-brown gelatinous masses of iron bacteria are abundant along the drifts, both where they cut the slate and where they cut the ore.

It seems probable that all the water issuing in the mine has at one time or another passed through the slate, and by its dissolving action on the disseminated iron sulphide and iron carbonate has become heavily loaded with iron. No analysis of the water has been made as yet, but it seems probable that the iron is in solution mainly as ferrous bicarbonate, though perhaps a part of it may be in the form of ferrous sulphate. These waters issuing from the mine openings either in the ore deposit or along the slate walls give abundant opportunity for the growth of bacteria.

The question naturally arises, How do the iron bacteria come into the mines? Are they carried by the waters themselves through intervening soil and rock or are they brought down into the mine on mine timbers, tools, or machinery? I have seen cultures of iron bacteria in places in mines where it seems quite improbable that they could have been brought by any other agency than the water itself, and it does not seem at all impossible that they may have been carried downward by surface waters through the larger openings in the soil or rock for many hundreds of feet. This opens the interesting possibility that iron bacteria may be active in fissures or other large underground openings entirely unconnected with mines and may thus be instrumental in the formation of many of the fissure deposits and replacement deposits of iron ore which are so common. Their presence in such localities is of course difficult to prove unless they should be actually found in underground openings which are penetrated during mining operations. Such a phenomenon to my knowledge has not been observed, but it might easily escape notice unless particular attention were called to it.

The cultures obtained from the Judson mine showed only *Spirophyllum*, and these were mainly in the form of short pieces of filaments. A peculiarity about these cultures, however, was that most of the filaments were thickly covered with small spherical bodies of the same brownish color as the filaments. (See fig. 9.) Whether these little bodies are granules of ferric hydroxide or whether they are conidia, as described by Ellis, has not been determined.

The occurrence of *Spirophyllum* associated with *Leptothrix* and *Gallionella* at the Kennedy mine, on the Cuyuna range in central Minnesota, has already been described.

In addition to these underground localities I have found *Spirophyllum* in a number of places in iron-bearing surface waters, but it occurs in clear, fresh waters rather than in stagnant bog waters like those in which *Leptothrix* is often found.

In the Vermilion iron-ore district of northern Minnesota I obtained cultures of *Spirophyllum* from two iron springs, both issuing at the bases of extensive ridges, composed largely of banded jasper and associated greenstone. One of these springs is at the base of Soudan Hill, on the south shore of Vermilion Lake; the other is at the western foot of Jasper Peak, a few miles south of Soudan.

At the spring on Vermilion Lake the water issues from an iron pipe at the base of a ridge consisting mainly of greenstone and jasper and some slate. It empties into a small basin from which it flows down a short slope into the lake. Brown scum occurs in the basin and for some distance along the little rivulet down toward the lake. Where the water is quiet the brown scum lies on the bottom and elsewhere it is attached to the sticks, grass blades, and other material lying in the water. The water has a strong iron taste.

At the spring at Jasper Peak the water comes directly out of the hillside into a small basin from which it flows through a series of larger pools into a marsh. Jasper Peak consists mainly of banded jasper and associated greenstone. A yellowish-brown scum of iron bacteria occurs at the bottom of the basin at the mouth of the spring and also in the pools in the marsh. It is not gelatinous but rather in the form of a fluffy precipitate.

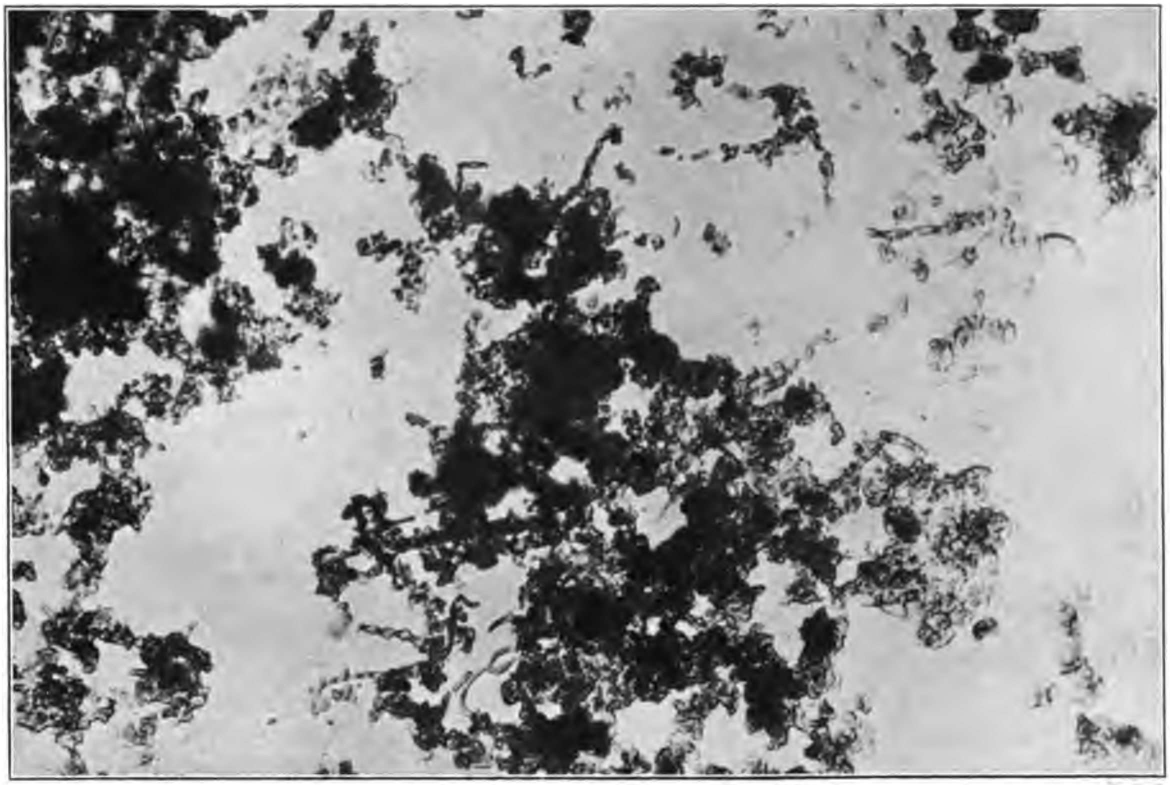
When examined microscopically the scum of iron oxide from both of these localities is seen to contain an abundance of threads of *Spirophyllum*, but with these threads is associated a large amount of brown flocculent, textureless material in large and small irregular masses. (See Pl. IX, *A*.) The textureless masses probably consist largely of ferric hydroxide, but whether this material is precipitated by simple chemical action or whether its formation is due perhaps to the activity of lower forms of iron-depositing bacteria has not been determined. Probably it results from simple oxidation. The *Spirophyllum* in these cultures is of medium size and has regular but not very close twisting. In general the threads are clear and do not have the deposits of granular material on them that is so characteristic of the cultures from the Judson mine. However, many of the granular masses of ferric hydroxide can be seen to contain spiral threads, these forming a sort of nucleus around which the ferric hydroxide collects.

In the Rowe and Hillcrest mines, in the Cuyuna iron range, both of which are open-pit mines in red and brown hematite, seepages of iron-bearing waters issue from glacial sand and gravel which overlie the iron ore. The iron is taken into solution by the water while it is percolating through the sand and gravel, probably being derived from iron silicates, carbonates, and sulphides disseminated through the glacial material.

Thin coatings of yellowish-brown scum cover the pebbles over which the water flows and this material upon examination is seen to consist of *Spirophyllum* associated with more or less granular and flocculent ferric hydroxide, which is probably a chemical precipitate. In localities like these iron bacteria develop in a surprisingly short time, deposits being formed by them within a week after the glacial sand and gravel are laid bare by stripping operations.

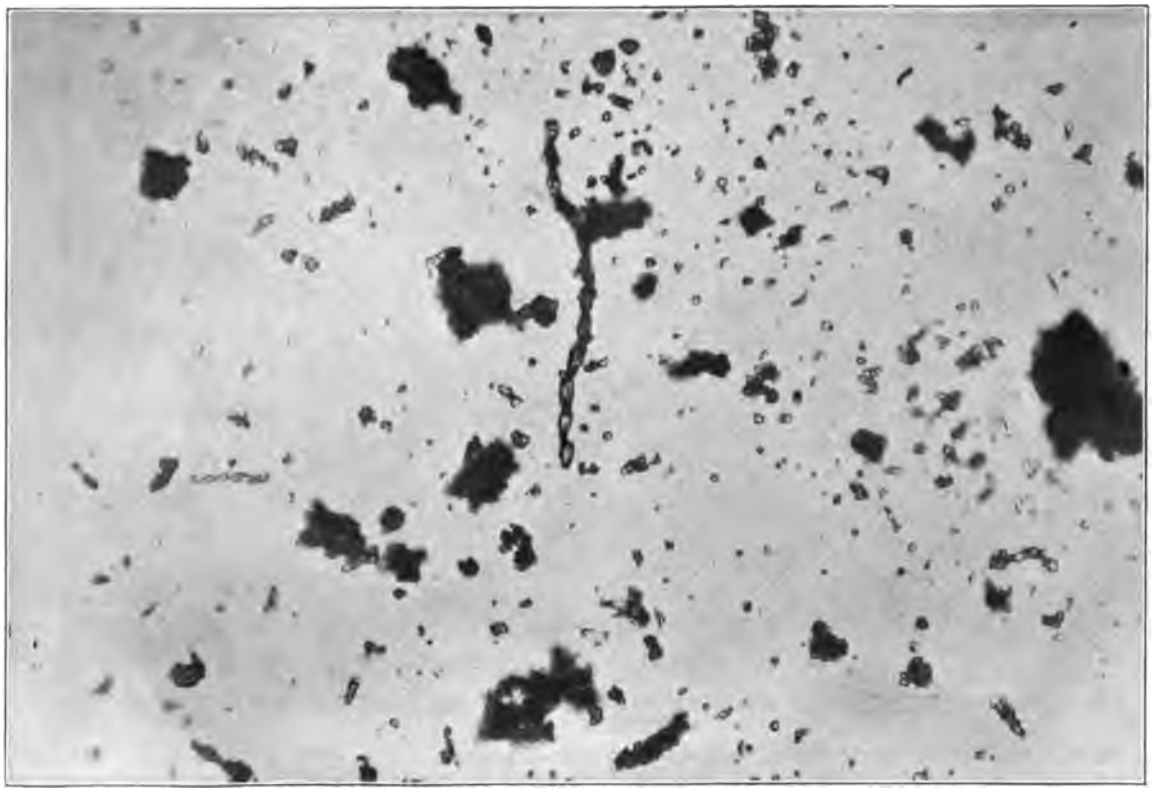
In the Pennington open-pit mine a very curious form of *Spirophyllum* was found. The water, which issues in the form of a small spring directly from the ore, apparently contains enough ferrous iron in solution to support a growth of iron bacteria. The material collected was brown in color and contained some *Spirophyllum* and algae. Upon standing for a week or so it became black, but over its surface a light-brown scum formed, which upon examination was found to consist of an almost pure culture of a variety of very small *Spirophyllum*. The threads are ribbon-like but very narrow and very loosely and irregularly twisted and are intergrown into a thick matting mixed with considerable granular ferric hydroxide. A great many of the threads show no twisting at all, and double ropelike threads are rare. There seems to be a great uniformity in the size of the threads, though here and there occur larger threads which resemble the ordinary *Spirophyllum* seen in other cultures.

At several points in the Pennington pit there are steel bars and rails which during the closed season for mining operations become submerged by water that accumulates in the pit. On several of these bars and rails I found beautifully developed porous tubercles of iron rust, which upon microscopic examination proved to contain abundant casts of *Spirophyllum*. (See Pl. IX, *B*, and fig. 13.) The greatest diameter of the tubercles is 2 inches or more at the base, and they rise from the surface of the bar or rail from a quarter to perhaps half an inch. The surface of such tubercles is formed by a thin, smooth, brittle film, and the interior consists of porous cellular ocherous material which on handling breaks up into fine powder. It is this material which contains abundant casts of *Spirophyllum*. Many of the casts still show the original texture of the threads clearly under the microscope, some of them being single and some double threads. Most of them, however, are thickly coated with granules of ferric hydroxide and appear like thick brown cords with rough surfaces. Some of these are twenty or more times the thickness of the original *Spirophyllum*. Frequently



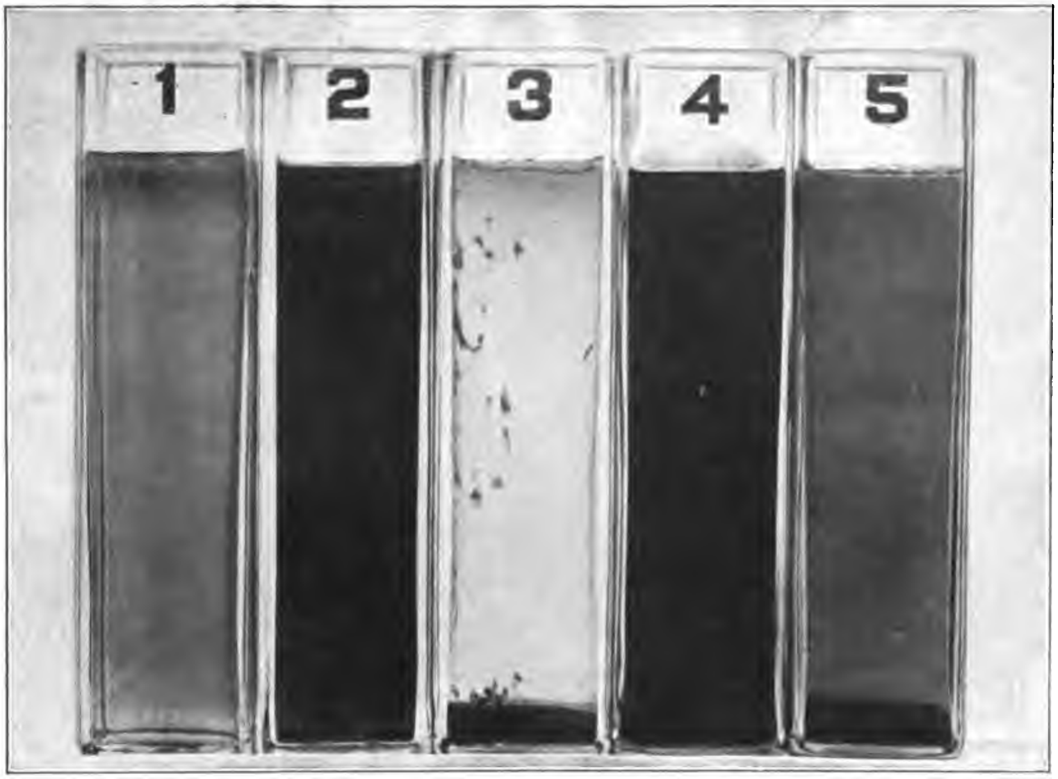
A. PHOTOMICROGRAPH OF OCHEROUS SCUM FROM IRON SPRING NEAR VERMILION LAKE, SOUDAN, MINN., ×640.

The dark irregular masses are ferric hydroxide. With it are mixed numerous forms of *Spirophyllum ferrugineum*, some double and some single. Unstained.



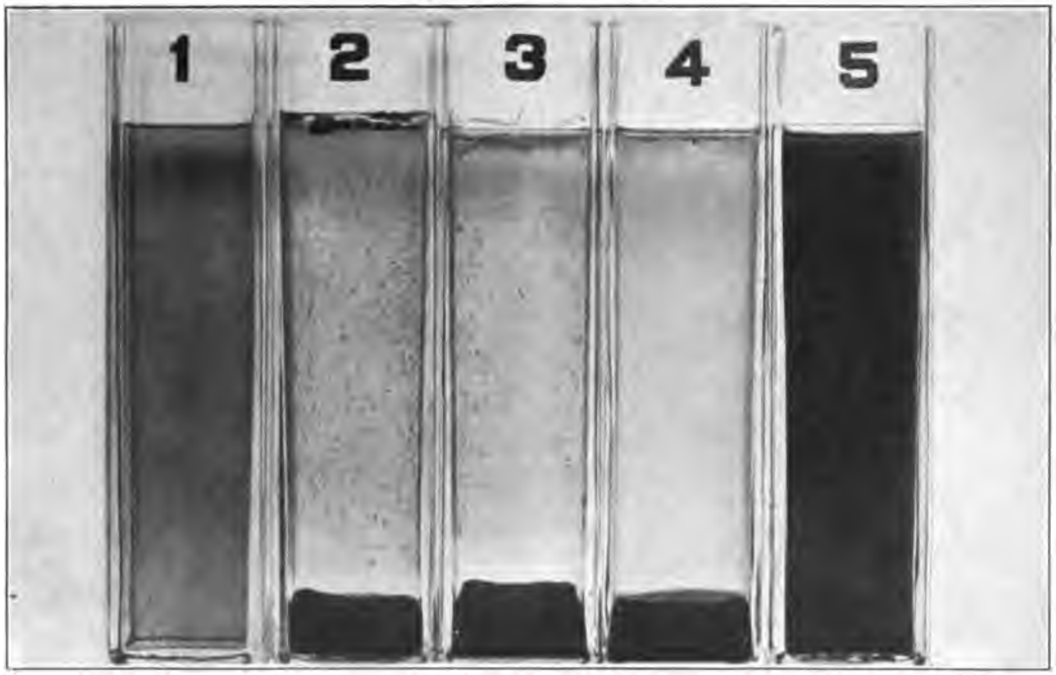
B. PHOTOMICROGRAPH OF LIMONITE POWDER FROM TUBERCLE OF IRON RUST, ×640.

Shows a number of scattered forms of *Spirophyllum ferrugineum* and irregular masses and scattered specks of granular iron rust. Unstained.



A. CULTURES SHOWING THE PRECIPITATION OF FERRIC HYDROXIDE FROM SOLUTIONS OF FERRIC AMMONIUM CITRATE.

1, Water with freshly dissolved ferric ammonium citrate; 2, water from Lake Mendota, Wis., with ferric ammonium citrate after standing one month; 3, city water, Madison, Wis., which contained ferric ammonium citrate but from which the iron has been precipitated as ferric hydroxide; 4, water with hay infusion containing freshly dissolved ferric ammonium citrate; 5, water with hay infusion which contained ferric ammonium citrate but from which the iron has been precipitated as ferric hydroxide.



B. CULTURES SHOWING THE PRECIPITATION OF FERRIC HYDROXIDE FROM SOLUTIONS OF FERRIC AMMONIUM CITRATE.

1, Water with freshly dissolved ferric ammonium citrate; 2, water from Lake Mendota, Wis., which contained ferric ammonium citrate but from which the iron has been precipitated as ferric hydroxide; 3, city water, Madison, Wis., which contained ferric ammonium citrate but from which the iron has been precipitated as ferric hydroxide; 4, water from iron spring near Lake Kegonsa, Wis., which contained ferric ammonium citrate but from which the iron has been precipitated as ferric hydroxide; 5, distilled water with ferric ammonium citrate after standing one month.

they are intertwined to form networks. Besides the threads and cordlike forms an abundance of small specks and granules of ferric hydroxide occur, and also large irregular masses of granules which do not show the cordlike forms.

Spirophyllum was originally cultivated in the laboratory by Lieske.[1] In his first attempt he used sand and old leaves obtained from a stream in which *Spirophyllum* occurred. He placed this material in a vessel, added to it a thin iron wire, and then filled the vessel with water from the public supply of the city of Dresden. In this manner he obtained an abundant growth of *Spirophyllum*. Later he used an Erlemeyer flask containing water from the same system to which had been added a small amount of extract of old leaves and thin iron wire or coarse filings. After three or four days *Spirophyllum* had developed. By making transfers to sterile flasks he was able to obtain approximately pure cultures.

He finally obtained pure cultures in a specially prepared culture medium through which carbon dioxide was passed. The medium had the following composition:

Composition of culture medium used by Lieske.

$(NH_4)_2SO_4$	grams	1.5
KCl	do	.05
$MgSO_4$	do	.05
K_2HPO_4	do	.05
$CaNO_3$	do	.01
Distilled water	cubic centimeters	1,000

Erlemeyer flasks of 100 cubic centimeters each were filled up to 2 centimeters with this medium and after sterilization were allowed to stand in atmospheric air for two days. Coarse iron filings, which had been dry sterilized at 160° C. for one hour, were then added, 0.05 gram being used for each flask. The flasks were then inoculated with a small amount of culture of iron bacteria, placed under a bell jar in a cool place, and carbon dioxide was added up to 1 per cent. This resulted in the formation of ferrous bicarbonate in the solution to the amount of about .0.01 per cent. *Spirophyllum* developed in four days. By repeated transfers to sterile flasks pure cultures were obtained.

Spirophyllum occurs as flat unbranched ribbon-like filaments twisted spirally about the longer axis. There appears to be no differentiation between the two ends of the filaments, and apparently no variation in the width or the thickness of the filament from end to end. Along the edges, however, they are somewhat thicker than along the center. Like *Leptothrix*, *Spirophyllum* is always colored yellowish brown to brown from the ferric hydroxide in the filament. I have not been able to stain it satisfactorily with any of the common aniline stains.

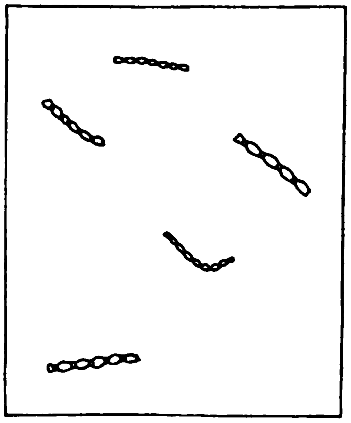


FIGURE 9.—Various forms of *Spirophyllum ferrugineum*. Drawing with camera lucida. × 550.

The closeness of the spiral twisting of *Spirophyllum* varies with the individual; possibly there may be several species. Some filaments are very loosely twisted, but others are very closely twisted. In some the twisting is irregular, varying in closeness in different parts of the filament, whereas in others it is very regular and diagrammatic. (See figs. 9, 10, and 11, and Pls. IV, *B;* V, *A;* VI, *A;* VII; VIII, *A;* and IX, *A.*) This difference may indicate a separation into different species. In some cultures there are numerous filaments which are bent in the middle and the ends of which have been twisted about each other around a common axis, as in *Gallionella*. In such an individual the two ends frequently form a fork, thus giving it the appearance of a single branching filament. (See Pl. VII, *A.*) More often, however, the two filaments forming such a thread can be traced with more or less distinctness. (See Pl. VII, *B.*)

In the cultures examined I have found *Spirophyllum* to vary in width from 1 to 3 micra, the average width being perhaps a little over 2 micra. The longest filaments that have come to my notice were about 0.1 millimeter in length. However, the filaments are very brittle and, like those of *Leptothrix*, are easily broken during mounting operations.

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[1] Lieske, Rudolf, Beiträge zur Kenntnis der Physiologie von *Spirophyllum ferrugineum* Ellis: Jahrb. wiss. Botanik, Band 49, pp. 91–127, 1911.

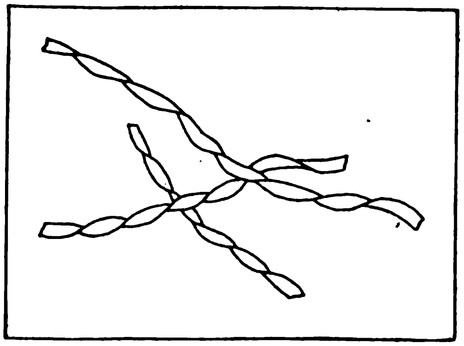

FIGURE 10.—Irregularly twisted forms of *Spirophyllum ferrugineum*. Drawing with camera lucida. × 1,080.

Up to the present time no cell structure has ever been observed in *Spirophyllum* by any investigator. The organism appears to consist of simple, flat, ribbon-like filaments, undifferentiated in its parts and without visible interior structure.

According to Lieske[1] the only method of reproduction of *Spirophyllum* is by fragmentation—that, is, by the breaking off of pieces of filaments and their growth into new filaments. Ellis,[2] however, claims that *Spirophyllum* reproduces by means of conidia, which grow as small spherical bodies on the flat sides of the filament and gradually become detached and are carried away, eventually germinating and forming new filaments. Ellis gives descriptions of the conidia and of their germination. Lieske, who did much careful work on the growth and isolation of *Spirophyllum*, does not credit these observations of Ellis, believing that what Ellis saw were probably foreign bodies attached to filaments of *Spirophyllum*.

During my own observations I have found many cultures of *Spirophyllum* in which not a trace of the formation of conidia was visible. However, certain other cultures that I have examined, especially those from the Judson mine, show filaments of *Spirophyllum* which are covered with small spherical, elliptical, or oval bodies, sometimes so thickly as to conceal the filament itself. (See fig. 12 and Pls. VIII and IX, *A*.) These bodies are colored brown just like the filament and average about two-thirds of a micron in diameter. I have not seen these bodies in the process of germination, so that I can not say whether they are conidia or whether, as seems more probable, they are small, chemically precipitated granules of ferric hydroxide. Although usually ferric hydroxide is precipitated in the form of structureless gelatinous masses, it is frequently found in the granular form as well. It also seems possible that these bodies might be lower iron-depositing bacteria of the coccus or bacillus types which live under the same conditions as *Spirophyllum* and might readily become attached to the filaments in large numbers.

Spirophyllum was first described as a separate species by Ellis[3] in 1907. Previously it had been included under the species *Gallionella* first described by Ehrenberg in 1836, which included also other types of iron bacteria. After *Leptothrix*, *Crenothrix*, *Clonothrix*, and others had been described as distinct genuses, Ellis found that the organisms still grouped under the term *Gallionella* were of two types very closely related in occurrence and general characteristics. One of these consisted of a double twisted cylindrical thread and the other of a twisted ribbon-like thread. He named the latter *Spirophyllum ferrugineum*, applying the name *Gallionella* only to the cylindrical threads. Molisch,[4] in his work published in 1910, does not accept Ellis's classification and believes that the two types distinguished by Ellis are merely different forms of the same organism. He calls the ribbon-like form *Gallionella ferruginea* var. *lata*. Lieske, in his work with

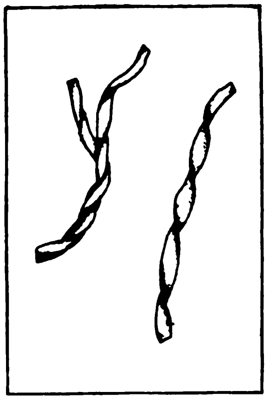

FIGURE 11.—Single and double twisted ribbon-like forms of *Spirophyllum ferrugineum*. Drawing with camera lucida. × 1,080.

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[1] Lieske, Rudolf, op. cit.

[2] Ellis, David, A contribution to our knowledge of the thread bacteria: Centralbl. Bakteriologie, Abt. 2, Band 19, pp. 507–512, 1907.

[3] Ellis, David, On the discovery of a new genus of thread bacteria (*Spirophyllum ferrugineum* Ellis): Roy. Soc. Edinburgh Proc., vol. 27, pt. 1, p. 21, 1907.

[4] Molisch, Hans, Die Eisenbakterien, 1910.

Spirophyllum, does not commit himself with regard to the classification but seems rather inclined to believe that *Spirophyllum* is a distinct genus. He gives the differences between *Gallionella* and *Spirophyllum* as follows: (1) *Spirophyllum* is ribbon-shaped whereas *Gallionella* is cylindrical. (2) *Spirophyllum* is not found with two strands twisted around each other, but only as single strands. (3) *Spirophyllum* is twisted around its own longitudinal axis whereas *Gallionella* is twisted around an axis outside of the thread. (4) *Spirophyllum* grows into longer threads than *Gallionella*. (5) In cultures of *Spirophyllum* the typical form always develops and transitions to *Gallionella* are never seen. Lieske apparently never observed double strands of *Spirophyllum* probably because he was working mainly with artificial cultures. In nearly all cultures growing under natural conditions double strands are very common. *Spirophyllum*, therefore, is twisted about an axis outside of the thread just as is *Gallionella*. The other differences between the two forms, however, exist.

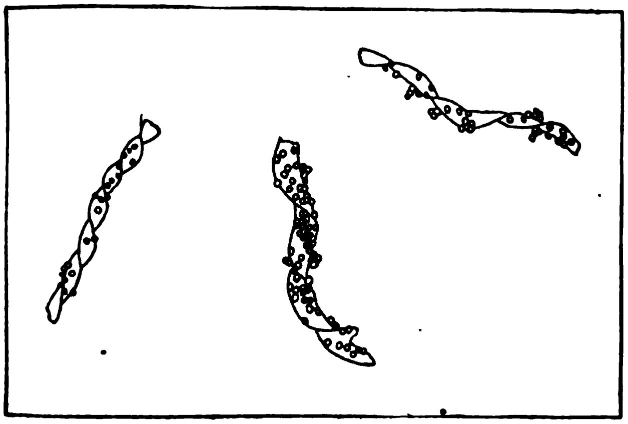


FIGURE 12.—Irregularly twisted forms of *Spirophyllum ferrugineum* with granular coatings probably consisting of ferric hydroxide. Drawing with camera lucida. × 1,080.

After examining cultures of iron bacteria from many different localities it appears to me that Ellis's view is probably reasonable. Although the two forms are undoubtedly closely related, there seem to be no gradational forms from one to the other and one form may be present in cultures to the exclusion of the other. There is, however, a danger of confusing double strands of *Spirophyllum* with those of *Gallionella*. Usually the ribbon-like form of the threads is clearly seen, but occasionally, where the twisting is very close, the dobule threads greatly resemble those of *Gallionella*.

OTHER IRON-DEPOSITING BACTERIA.

Besides the group of iron thread bacteria, the most important members of which have just been described, two groups of lower iron-depositing bacteria are commonly present in soils and natural waters—(1) those which precipitate ferric hydroxide or basic ferric salts, and (2) those which precipitate ferrous sulphide. To the first group belong *Siderocapsa treubii* and its relatives described by Molisch as being abundant in natural iron-bearing waters from which they deposit ferric hydroxide, and also certain other lower bacteria that occur in soils and natural waters and that precipitate ferric hydroxide or basic ferric salts from solutions of organic iron salts. To the second group belong the sulphate-reducing bacteria and the hydrogen sulphide forming bacteria which are commonly present wherever decaying organic matter is found.

It has been known for a long time that many natural iron-bearing waters contain types of bacteria such as have been described which deposit ferric hydroxide, but it has not been known that practically all soils and all natural waters contain bacteria which are capable of precipitating ferric hydroxide or basic ferric salts from solutions of certain organic iron salts. These organisms are not iron bacteria proper in the sense that they require iron in

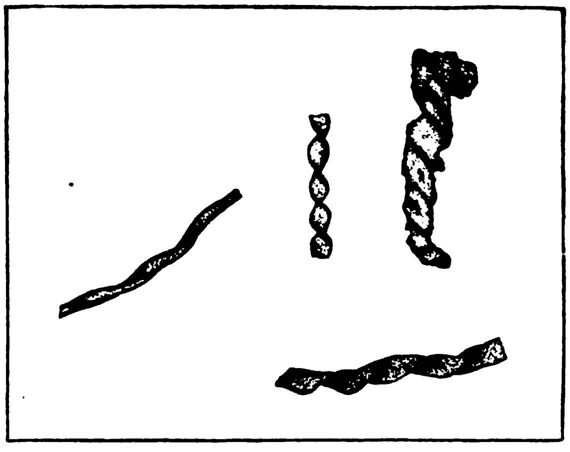


FIGURE 13.—Various forms of fossil *Spirophyllum ferrugineum* from tubercle of iron rust. × 1,080.

solution for their development. It appears rather that they use other constituents present in the iron salts and that ferric hydroxide is thrown down as a waste product. In the course of my experiments I have noted the presence of such organisms in various natural waters, such as well water, lake water, river water, and spring water, and have also found them in different kinds of soil, such as silt, loam, clay, and sand. It seems probable that many of the common types of soil and water bacteria are active in the precipitation of ferric hydroxide or basic ferric salts from solutions which contain organic iron salts.

Up to the present time I have succeeded in isolating several individual types which precipitate iron. Although I have worked with different organic and inorganic solutions and have prepared cultures in liquid media that precipitated the iron from solutions of several organic iron salts, all the organisms which I have isolated and studied have been grown on solid media containing ferric ammonium citrate. Most of the other iron salts that I have used are unsatisfactory to work with, some, especially the inorganic salts, because they oxidize or hydrolyze too readily, and others because they render the media unfavorable for growth because of their toxic nature, harmful reaction, or other characteristics.

In experimenting with the precipitation of iron from solution by organisms it is, of course, necessary to use iron salts, which are readily soluble and which are not precipitated on account of oxidation when exposed to the atmosphere or when subjected to sterilization. Besides, the solutions must not be either too acid or too alkaline to sustain organic life. In my work I have used the following organic iron and manganese salts in culture media:

Organic iron and manganese salts used in culture media.

	Reaction to litmus.
Ferric ammonium citrate	Very slightly acid.
Ferric citrate	Acid.
Iron acetate	Acid.
Iron lactate	Slightly acid.
Ferric oxalate	Acid.
Albuminized iron	Neutral.
Manganese citrate	Acid.
Manganese acetate	Slightly acid.

Of these salts I have found ferric ammonium citrate to be the most satisfactory, because (1) it is readily soluble, (2) it does not produce an unfavorable reaction, and (3) it is resistant to ordinary oxidation processes.

The solutions of inorganic iron salts tested in attempts to produce cultures of ferric hydroxide precipitating bacteria were ferrous sulphate, ferrous ammonium sulphate, ferrous carbonate, and ferric chloride. Deposits of ferric hydroxide formed in these solutions under some conditions but the formation was always readily explained as due to simple hydrolysis or to oxidation and hydrolysis rather than to the action of organisms.

The bacteria which produce hydrogen sulphide and those which reduce ferrous sulphate and thus precipitate ferrous sulphide from solution have also long been known, and many of them have been isolated and studied. The formation of ferrous sulphide by the bacteria which produce hydrogen sulphide is due to the action of hydrogen sulphide on iron salts in solution or on ferric hydroxide previously precipitated, whereas with the sulphate-reducing bacteria the formation is due to the removal of oxygen from the sulphate and this results in the precipitation of the sulphide directly.

Hydrogen sulphide is formed by bacteria in two ways—by the decomposition of sulphur-bearing proteins and by the reduction of sulphur. Many decay-producing bacteria have the power of changing organic sulphur compounds to hydrogen sulphide. When free sulphur is present with decomposing organic matter it is attacked through the action of bacteria and reduced to hydrogen sulphide as well. Hydrogen sulphide reacts with any iron salts present and forms ferrous sulphide.

A number of species of bacteria have been isolated which act on sulphates, reducing them to sulphides. Among these are *Proteus vulgaris*, *Vibrio hydrosulfureus*, and *Spirillum desulfuricans*. Some sulphate-reducing bacteria have the power of reducing also thiosulphates and sulphites. When the compounds thus attacked are iron compounds ferrous sulphide is formed directly and precipitated. If sulphides of other metals are formed they may be attacked by carbon dioxide, and hydrogen sulphide may be formed. Hydrogen sulphide will then react with the iron salts to form ferrous sulphide.

Cultures were made in liquid and solid media of the bacteria which reduce sulphates and those which produce hydrogen sulphide. Ordinary synthetic nutrient media were used for sulphate reducers, and ferrous sulphate was added for reduction to sulphide. Cultures of bacteria which produce hydrogen sulphide were made in solutions containing decomposing organic matter, organic iron salts such as iron lactate or iron tartrate being used as indicators of hydrogen sulphide formation.

Experiments on the precipitation of ferric hydroxide and ferrous sulphide from solutions of iron salts by various species of lower bacteria are described on the following pages.

EXPERIMENTS ON PRECIPITATION OF IRON FROM SOLUTIONS BY BACTERIA.

PRECIPITATION OF FERRIC HYDROXIDE AND BASIC FERRIC SALTS FROM FERRIC AMMONIUM CITRATE SOLUTIONS.

It was noted by Prof. E. B. Fred, of the University of Wisconsin, that when ferric ammonium citrate was added to jars containing water and marsh mud in which bacteria of various kinds were abundant, the deep reddish-brown color which it imparted to the solution disappeared after a few weeks, owing to the precipitation of the iron. It was supposed that this precipitation was caused by the activity of ordinary iron-depositing thread bacteria, and upon this supposition I started a series of cultures.

The first experiments were performed with the object of determining whether pure natural waters had the same effect in precipitating the iron from ferric ammonium citrate solutions as impure muddy cultures, and whether this action varied with different kinds of natural waters. For this purpose three glass jars were each filled with 500 cubic centimeters of water, the first one being filled with water from Lake Mendota, the second with water from the city wells of Madison, Wis., and the third with hay extract—that is, water in which hay had been boiled. To each of these jars 2.5 grams of ferric ammonium citrate was then added. They were allowed to stand at room temperature (about 18° C.) for one month and were then photographed. (See Pl. X, *A*.) The results are well shown in the photograph. Jar No. 1 shows the appearance of the freshly prepared ferric ammonium citrate solution in clear water, and jar No. 4 shows the same in hay extract. Jar No. 2 contains water from Lake Mendota with ferric ammonium citrate. It shows that decided bacterial action has taken place after one month, but no precipitate has formed. This jar was allowed to stand for another month and at the end of that time the iron had been completely precipitated. Jar No. 3 contains water from Madison city supply, which has had the same treatment as jar No. 2. It will be seen that in this jar the iron had been completely precipitated after one month, the solution being perfectly clear and transparent. Tufts of ferric hydroxide are attached to the inside surface of the jar and a thick deposit of ferric hydroxide with perhaps some basic ferric salts occurs at the bottom. Jar No. 5 contains extract of hay which has had the same treatment as jars Nos. 2 and 3. It will be seen that here also complete precipitation of the iron has taken place within one month, leaving a clear solution, which, however, is somewhat darker on account of the hay extract it contains.

Having obtained these results it was thought best to duplicate the experiment with slight variations. A set of four jars was therefore prepared, each being filled with 500 cubic centimeters of a different type of water. Two and one-half grams of ferric ammonium citrate were added to each. Two of these jars contained water from Lake Mendota and from the Madison city supply as before. A third, however, was filled with water from an iron spring near Lake Kegonsa, about 14 miles southeast of Madison. This spring contained an abundant growth of *Leptothrix*. A fourth jar was filled with distilled water. The jars were allowed to stand at room temperature and were photographed after five weeks. (See Pl. X, *B*.)

Jar No. 1 again shows the appearance of the freshly prepared solution of ferric ammonium citrate in clear water. Jar No. 2 and jar No. 3 show the action of water from Lake Mendota and from the Madison city supply respectively on ferric ammonium citrate in solution. Both waters precipitated the iron after four weeks. The masses of ferric hydroxide and perhaps some basic ferric salts are seen at the bottoms of the jars. Jar No. 4 contained iron spring water. The precipitation of ferric hydroxide took place in this jar also after about four weeks. Jar No. 5 contains distilled water with ferric ammonium citrate in solution. Some bacterial action has taken place after five weeks, as is shown by the darkening of the solution. Complete precipitation of ferric hydroxide in this jar, however, did not take place until after about seven or eight months.

In order to see whether soil would have the same effect as natural waters on iron ammonium citrate in solution, several flasks containing 500 cubic centimeters of water with 2.5 grams of ferric ammonium citrate in solution were each inoculated with 20 grams of a different kind of soil—a black loamy soil, brown sandy soil, or clayey soil. Precipitation of ferric hydroxide took place in these jars after about two weeks, which showed a more rapid action with soils than with natural waters.

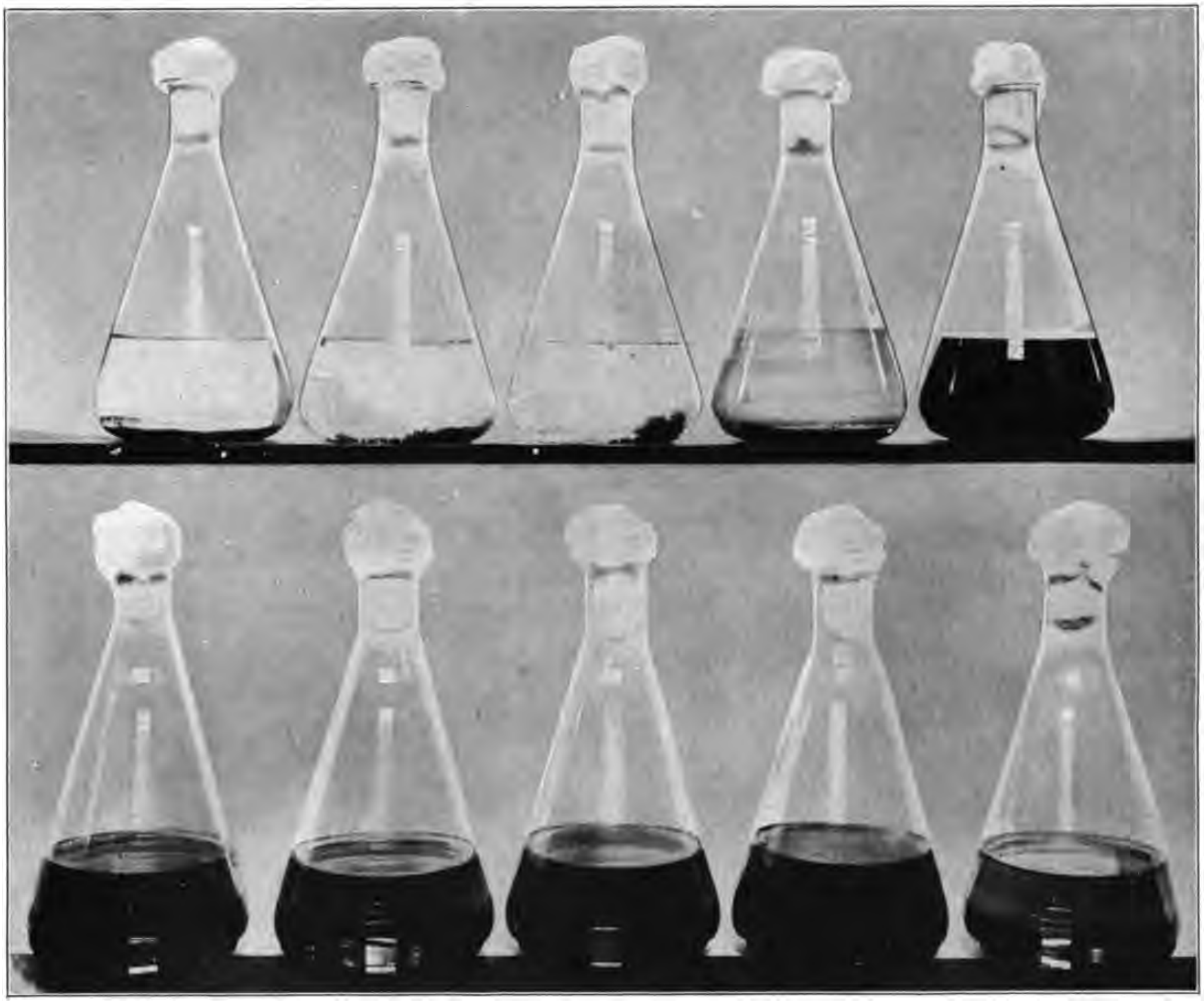
Although the results of the preceding experiments seemed to show fairly conclusively that the precipitation was due to biologic agencies rather than to chemical processes, it seemed best to make sure of this point. There are some iron salts, especially inorganic but also organic, in which precipitation occurs on account of oxidation or on account of hydrolysis, the precipitates consisting either of ferric hydroxide or of basic organic or inorganic ferric salts. In order to show conclusively that the precipitating action was due to biologic agencies, the following experiment was performed. Two sets of five flasks of 1,000 cubic centimeters capacity were prepared with culture solutions, one set being a duplicate of the other. Each of the flasks contained 500 cubic centimeters of water in which 2.5 grams of ferric ammonium citrate were dissolved. The differences between the culture solutions in the different flasks were as follows: The first flask in each set contained water from the city supply of Madison, Wis.; the second, water from Lake Mendota; the third, water from the iron spring near Lake Kegonsa; the fourth, water inoculated with 20 grams of garden soil; and the fifth, distilled water. One of these sets was sterilized, so as to stop all organic action, whereas in the other set the organisms were allowed to develop freely, as in the previous experiments. The flasks are shown in Plate XI, those of the lower row being sterilized duplicates of those of the upper row. The sterilization consisted in heating the flasks and contents in an autoclave at 130° C. for 15 minutes.

Both sets of flasks were allowed to stand at room temperature for four months, at the end of which time the photograph was taken. As may be clearly seen, the contents of the lower row of flasks have suffered no change, whereas in the upper row the contents of all the flasks except the fifth have suffered complete precipitation of the iron in solution. The fifth flask, which contains distilled water, shows only a darkening of the solution. The time of precipitation varied in the different flasks. The water from the city supply of Madison precipitated the iron from solution in about two months, the water from Lake Mendota in about seven weeks, the iron spring water in about one month, and the soil infusion in about two weeks.

This experiment showed conclusively that the sterilized material did not suffer precipitation of the iron in solution. There still remained the possibility, however, that during the process of sterilization the iron salt in solution might have suffered some change which rendered it less subject to hydrolysis. To investigate this possibility several of the sterilized solutions, after having stood for four months, were reinoculated with a small amount of fresh soil infusion. This resulted in the precipitation of the iron within a very short time and showed beyond doubt that the precipitation of the iron was due to biologic agencies.

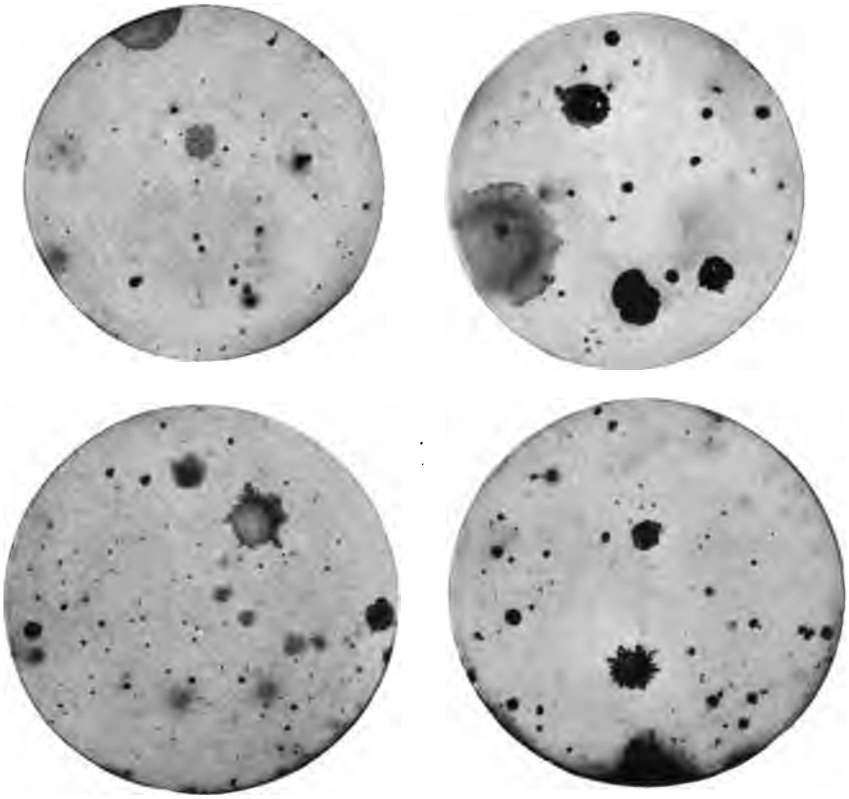
While these experiments were being conducted the precipitates were frequently examined. The material forming the deposits was reddish brown and flocculent and resembled the ferric hydroxide which is precipitated when ammonium hydroxide is added to a solution of a ferric salt, such as ferric chloride or ferric nitrate. It usually settled to the bottom of the containing vessel and after standing for some time became compacted into a fluffy, gelatinous deposit. After prolonged standing it contracted and changed from reddish brown to dark brown in color.

At the outset it was supposed that upon microscopic examination this material would be found to consist mainly of matted threads of iron bacteria such as I had already seen in gelatinous iron scums from many localities. I found, however, that the precipitate ap-

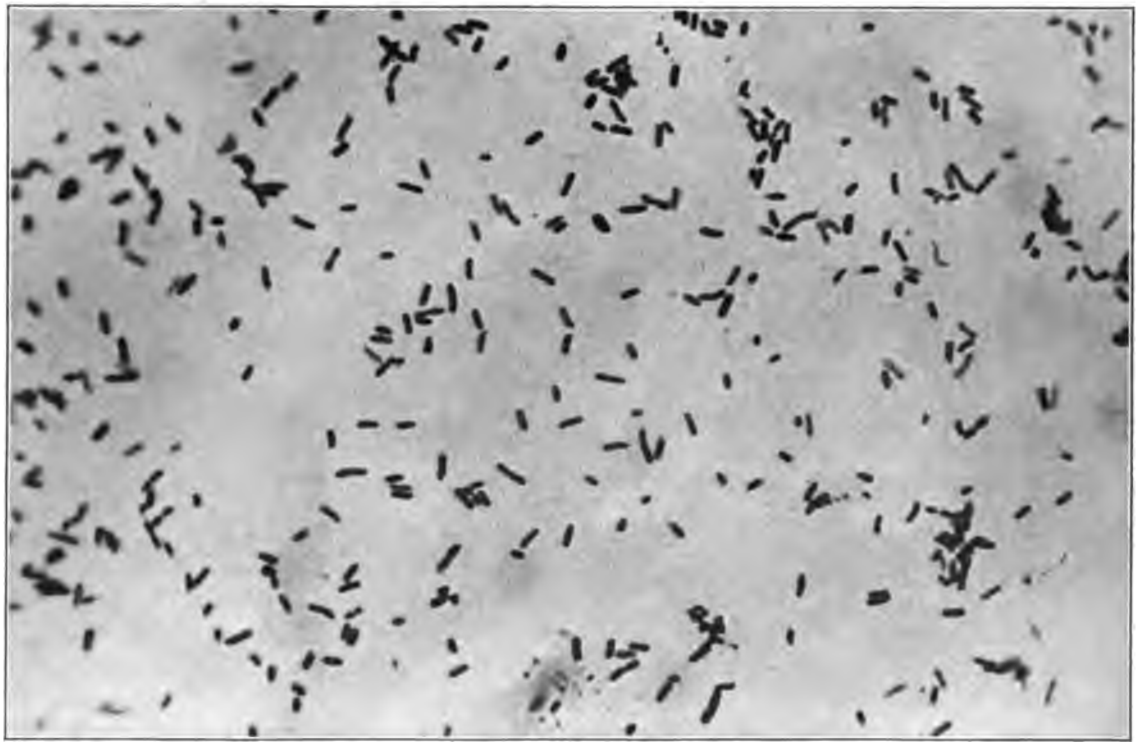


CULTURES SHOWING THE EFFECT OF STERILIZATION IN THE PRECIPITATION OF FERRIC HYDROXIDE FROM SOLUTIONS OF FERRIC AMMONIUM CITRATE.

Upper row, natural waters which contained ferric ammonium citrate but from all but one of which the iron has been precipitated as ferric hydroxide by bacteria; lower row, different waters containing ferric ammonium citrate in solution which were sterilized before bacteria had an opportunity to precipitate the iron. The flasks of the lower row are duplicates of those of the upper row. The first flask in each row contains Madison city water; the second, water from Lake Mendota; the third, iron-spring water; the fourth, water with soil; and the fifth, distilled water.



A. PETRI DISHES SHOWING COLONIES OF LOWER BACTERIA WHICH PRECIPITATE FERRIC HYDROXIDE FROM AGAR CONTAINING FERRIC AMMONIUM CITRATE.



B. PHOTOMICROGRAPH OF A PURE CULTURE OF ONE TYPE OF LOWER BACTERIA WHICH HAS THE POWER OF PRECIPITATING FERRIC HYDROXIDE FROM SOLUTIONS OF FERRIC AMMONIUM CITRATE, × 1,310.

Stained with carbol fuchsin.

peared light brown, transparent, and was apparently colloidal. There were no traces of iron bacteria in the material, except that in the flask containing iron spring water a few threads of *Leptothrix* were found. These threads probably develop in ferric ammonium citrate solutions to some extent, as was determined by Molisch.[1] Many of the threads, however, were probably present in the water before the ferric ammonium citrate was added. Upon prolonged standing I found that mold mycelia frequently developed in the gelatinous material and sometimes became quite abundant. There appear to be several varieties of molds which grow in these solutions, but I have not attempted to identify or describe them.

A partial analysis was made by W. G. Crawford, of the University of Wisconsin, of the precipitate formed from a solution of ferric ammonium citrate in water from the city supply of Madison with the following result:

Analysis of precipitate formed from solution of ferric ammonium citrate.

[Dried at 105° C.]

Ferric oxide (Fe_2O_3)	72.50
Combined water (H_2O)	7.11
Loss above 105° C. (exclusive of combined water)	20.12
	99.73

The material was examined qualitatively for traces of citrate in order to determine if basic ferric citrate was present in the precipitate. The indications of its presence were very slight, however. It appears from the analysis, therefore, that the material is one of the less hydrated forms of ferric oxide, approaching goethite in composition. A percentage of 72.50 ferric oxide requires 8.15 per cent combined water to form goethite. However, the analysis only shows 7.11 per cent of combined water, which probably means that the material is between goethite ($Fe_2O_3.H_2O$) and turgite or hydrohematite ($2Fe_2O_3.H_2O$) in composition. It is possible, however, that insoluble basic ferric citrate is precipitated with the ferric hydroxide, but that upon standing the citrate radicle is gradually used up by the bacteria, finally leaving only ferric hydroxide in the precipitate. The composition of the precipitate would, therefore, change with the time it is left standing and probably also with the treatment it receives previous to analysis, such as washing.

The large percentage of loss above 105° C. besides the combined water is difficult to explain, because of the small amount of organic matter visible in the precipitate when examined microscopically. It is possible, however, that besides the mold mycelia there are present abundant remains of lower bacteria which developed in the solution and which would be difficult to identify with the microscope.

The series of experiments performed up to this time made the following points evident: (1) That the precipitation of iron from solutions of ferric ammonium citrate is due to some biologic agency; (2) that the precipitate is hydrated ferric oxide with perhaps a small amount of basic ferric citrate; and (3) that it consists of a colloidal, textureless mass in which bacterial forms are unrecognizable. The latter fact seems to indicate that, as the ferric hydroxide is not taken up by the cells of the organisms causing the precipitation, it is probably only a waste product, other constituents of the salt, such as citric acid or ammonia, being utilized and the ferric hydroxide thrown down.

In order to determine whether oxygen is necessary for the precipitation of ferric hydroxide or whether the action could take place under anaerobic conditions, carbon dioxide was run continuously for several weeks through ferric ammonium citrate solutions inoculated with soil. This produced a saturation of the solution with carbon dioxide and caused the removal of practically all traces of oxygen. The precipitation, however, took place as before.

Solutions prepared and inoculated with soil in the same manner as those mentioned above were placed under a bell jar and all the air removed, so as to produce a vacuum capable of supporting a mercury column 23.5 inches high. This reduction of air did not seem to affect the precipitation, which occurred after about the same period of time had elapsed as was required for similar cultures in the open air.

What remained now to be done was to isolate the organisms which threw the iron out of solution and to study their morphology and the conditions under which they are active. It required considerable experimental work before I succeeded in cultivating the organisms on solid media.

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[1] Molisch, Hans, Die Eisenbakterien, pp. 34, 35, 1910.

The first attempt was made with 1.5 per cent washed agar, containing no nutrient material. To this substance 0.5 gram of ferric ammonium citrate was added for every 100 cubic centimeters of agar. Plates were poured from this medium and were inoculated from various impure cultures. They were then allowed to incubate at room temperature for several weeks. Numerous colonies of different kinds of microorganisms developed on the plates, but none caused the precipitation of ferric hydroxide from the agar.

The second attempt was made by adding nutrient material in the form of soil and hay extract such as is used in media for protozoa. The agar was so prepared that 1,500 cubic centimeters of 1.5 per cent agar contained 50 cubic centimeters of hay and soil extract and 7.5 grams of ferric ammonium citrate. Plates were poured from soil infusion prepared by adding 20 grams of soil to a 400 cubic centimeter sterile water blank, then transferring 25 cubic centimeters of this infusion to another 400 cubic centimeter sterile water blank, and so on to the fifth dilution. Inoculations were made from the fourth and fifth dilutions, 1 cubic centimeter being used for each plate. Abundant growth of various organisms occurred on the plates after several days, but again there was no precipitation of ferric hydroxide.

In the third attempt, which was successful, Heyden Nährstoff agar was used as a medium and ferric ammonium citrate was added to it in the proportion of 1 gram of ferric ammonium citrate to 100 cubic centimeters of agar. Inoculations were made from soil infusion prepared as already described. The plates were incubated at a temperature of 28° C. for three or four days, and by that time showed an abundant development of microorganisms. (See Pl. XII, *A*.) Even after the second day certain of the colonies were seen to develop a dark-brown halo around them, and after five or six days these colonies became very dark brown and opaque and developed an iridescent surface owing to the precipitated ferric hydroxide. The plates inoculated with soil infusion of the fourth dilution gave much more satisfactory results than the plates inoculated with soil infusion of the fifth dilution.

Several kinds of colonies of bacteria precipitating ferric hydroxide developed under these conditions. The most typical ones were irregular flat colonies with ragged corrugated or feathery edges, most of them lying on the surface of the agar. These precipitated ferric hydroxide almost immediately after they began to develop, and after five or six days became coated with a brittle, dark-brown crust of ferric hydroxide, whose surface was shining and generally iridescent.

Another type of colony around which ferric hydroxide begins to precipitate soon after it develops is large and flat but differs from the preceding type in having smooth edges and a moist surface. This type does not become as dark and opaque as the preceding one.

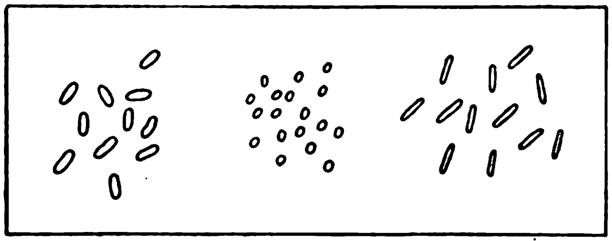

FIGURE 14.—Various forms of lower bacteria which have the power of precipitating ferric hydroxide from solutions of ferric ammonium citrate. × about 1,350.

There are a few other types of colonies of microorganisms which begin to precipitate ferric hydroxide soon after they appear on the agar. They are mainly small circular colonies which do not show any distinctive characteristics.

After a considerable period a great many other colonies on the plates begin to develop dark areas around them. Among these are small, raised, fluffy white colonies of *Actinomyces* and several varieties of small, raised cream-colored bacterial colonies. Some of these develop a small dark spot in the center. Bacteria from a number of the colonies were examined microscopically and it was found that there were several distinct species of organisms, some of them bacillus and some coccus forms. (See fig. 14.)

Slopes of Heyden Nährstoff agar, to which ferric ammonium citrate had been added, and also of bouillon agar similarly treated were inoculated from various colonies and the resulting streak cultures showed abundant formation of ferric hydroxide. Slopes of Heyden Nährstoff agar to which no ferric ammonium citrate had been added were similarly inoculated but showed practically no growth. Slopes of Heyden Nährstoff agar which contained manganese citrate also showed no growth. On the other hand, slopes of Heyden Nährstoff agar to which sodium citrate had been added showed considerable growth upon inoculation, and the same was true of plain bouillon agar, either with or without the addition of sodium citrate.

Pure cultures were made by inoculating another set of plates with organisms from one of the colonies which showed the most abundant formation of ferric hydroxide. These plates showed two distinct types of colonies as follows: (1) Circular, flat colonies with irregular corrugated edges formed on the surface of the agar. These colonies were quite thin and resembled the colonies already described as forming on plates of impure cultures. The formation of ferric hydroxide by the organism composing these colonies began in a few days. (2) Within the agar colonies of another type developed. These were very small, light-brown, lenticular colonies which commenced the formation of ferric hydroxide only after a week or two. There is little doubt that these two types of colonies were produced by the same species of microorganism, the difference being due to the different conditions under which they grew.

The organism composing these pure cultures was examined under the microscope and was found to be a short bacillus averaging about 1.4 micra in length, and about 0.5 micron in thickness. (See Pl. XII, *B*.) It was found to be difficult to stain, owing probably to the presence of ferric hydroxide in the cell walls. Upon prolonged treatment with carbol fuchsin, however, it assumed a distinct red color.

An attempt was made to determine the composition of the material precipitated from solution by a pure culture of this bacillus. For this purpose two flasks were prepared with the following culture solutions, the first being a synthetic medium and the second an ordinary nutrient medium:

Media used to obtain a pure culture in solution of the bacillus shown in Plate XII, B.

Flask No. 1.

K_2HPO_4	grams	0.5
$MgSO_4$	do	.5
NH_4NO_3	do	.5
$CaCl_2$	do	.2
$NaNO_3$	do	.5
Ferric ammonium citrate	do	10.0
Distilled water	cubic centimeters	1,000

Flask No. 2.

Heyden Nährstoff	grams	7.5
Distilled water	cubic centimeters	250

Heated for 2 hours in a steamer and filtered; 1,000 cubic centimeters distilled water and 10 grams ferric ammonium citrate then added to filtrate.

The solutions were both sterilized in the autoclave and then were inoculated from pure cultures. The synthetic solution showed precipitation of the iron after an incubation period of about five weeks at room temperature (about 17° to 19° C.) The Heyden Nährstoff solution showed no precipitation of iron even after a period of four and a half months. The precipitate from the synthetic solution was analyzed by W. G. Crawford, University of Wisconsin, with the following results:

Analysis of precipitate from flask No. 1.

[Dried at 105° C.]

Ferric oxide (Fe_2O_3)	65.00
Phosphoric acid (P_2O_5)	7.60
Combined water (H_2O)	27.20
Chlorine (Cl)	Trace.
Sodium (Na)	[1] Trace.
Potassium (K)	None.
Calcium (Ca)	None.
Magnesium (Mg)	None.
Ammonia (NH_3)	None.
Nitrate radicle (NO_3)	None.
	99.80

A comparison of this analysis with the analysis of a similar precipitate obtained with impure cultures from a solution of ferric ammonium citrate to which no other nutrient material had been added (see p. 33) shows marked differences. In the analysis of the precipitate obtained from the impure culture the ferric oxide amounts to 72.50 per cent as compared with 65 per cent in the analysis under consideration, and there is in the pure culture 7.60 per cent of phosphoric acid, which is entirely lacking in the impure culture. The presence of phosphoric acid is easily explained as being due to the presence of phosphate in the synthetic medium. Phosphorus almost invariably comes down with ferric oxide or alumina upon precipitation. Another difference, however, and one much more difficult to explain, is that in the analysis from the impure culture combined water amounts to 7.11 per cent and the loss, exclusive of water, to 20.12 per cent, whereas in the analysis of the precipitate from the pure culture in the synthetic medium the combined water amounts to 27.20 per cent and the loss due to volatilizing other substances is nil. There may be several explanations for this difference. In the first place, the presence of phosphoric acid in addition to the iron oxide may require a much larger percentage of combined water than iron oxide alone. The presence of this substance, however, does not account for the absence of other constituents, such as organic matter, included under loss. This difference, however, may be accounted for in part by the fact that the precipitate from the synthetic medium, on account of its slimy consistency, required washing by decantation for three weeks in order to clean it and to prepare it for analysis. This washing may have resulted in dissolving out any basic citrate and other material that may have been present and which in the precipitate from the impure culture was not removed in the comparatively short period of washing (1 hour). According to Crawford, the water obtained from the precipitate from the synthetic medium varied with the amount of heat applied, being only 19 per cent when the medium was heated to 300° C. but increasing to 27.20 per cent when it was heated on platinum to as high a temperature as could be obtained. No distillation of carbon was noted. The material is therefore apparently a hydrous ferric phosphate of indefinite composition.

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[1] With spectroscope.

PRECIPITATION OF FERRIC HYDROXIDE AND BASIC FERRIC SALTS FROM OTHER SOLUTIONS CONTAINING ORGANIC IRON.

At the same time that the experiments were being performed with ferric ammonium citrate a number of other organic iron salts were used as culture media with varying results. In the first place a series of cultures was prepared by inoculating different solutions containing organic iron with soil in order to see what effect the organisms in the soil had on the different salts in solution. The following organic iron salts were used, 2 grams of the salt being dissolved in 300 cubic centimeters of water in each experiment and the solution inoculated with 20 grams of sandy soil.

Appearance and reaction of solutions containing organic iron inoculated with soil.

Ferric ammonium citrate	Solution clear, light brownish red. Slightly acid.
Ferric citrate	Solution clear, yellow with brownish tinge. Acid.
Ferric oxalate	Solution clear, light lemon-yellow. Acid.
Iron lactate	Solution clear, light reddish brown. Slightly acid.
Iron acetate	Solution dark reddish brown. Acid.
Iron albuminate (5 per cent Fe_2O_3).	Solution clear, light brownish red. Neutral.
Manganese citrate	Solution colorless. Acid.
Manganese acetate	Solution colorless. Slightly acid.

These cultures were kept in wide-mouthed bottles plugged with cotton, a small circular piece of sterilized filter paper being immersed in the solution in each bottle in order to cover the layer of soil at the bottom so as to prevent the precipitate that formed from mixing with the soil. They were allowed to incubate at room temperature for two months. Ferric ammonium citrate was used along with the other salts to serve as an indicator of the nature of the changes taking place in the other solutions. The organic manganese salts were used in order to determine whether the organisms would precipitate manganese from solution as well as iron. The following results were obtained:

From the ferric ammonium citrate solution flocculent, brownish-red ferric hydroxide was precipitated in about two weeks and formed tufts on the sides of the bottle and a thin layer on the filter paper. Mold mycelia developed abundantly in this upon standing. A thin brittle brownish film formed over the surface of the solution. The solution became colorless but remained turbid.

In the ferric citrate solution precipitation was only partial at the end of two weeks but was complete in about three weeks. The precipitate consisted of flocculent black material, which formed a layer about one-fourth inch thick on the filter paper. The nature of the precipitate is unknown. It may have been hydrous ferrous sulphide. A dark-brown to black thin brittle film developed on the surface of the solution and from it a matting of black filaments, probably mold, extended down into the solution. Mold mycelia also developed abundantly in the black precipitate on the filter paper, as shown by microscopic examination. The solution became clear and colorless.

The ferric oxalate solution gave a very thin, light-brown deposit on the filter paper and on the sides of the bottle in about one and one-half weeks. The nature of the deposit was not determined. A thin brown brittle film formed on the surface of the solution. The solution became slightly turbid and retained a brownish tinge even after standing for two months.

In the iron lactate solution the precipitation did not begin until after two or three weeks and was not complete even after two months. The precipitate was brownish red and flocculent and settled very slowly on the filter paper, so that at the end of two months the deposit was nearly one-half inch in thickness. Small masses attached themselves to the sides of the bottle. The solution remained light brownish owing to fine, suspended, flocculent material. Upon microscopic examination the precipitate was seen to consist mainly of colloidal material with here and there mold mycelia, some of which had a brown coating. The precipitate probably consisted of ferric hydroxide and more or less basic iron lactate.

From the iron acetate solution a flocculent reddish-brown material was precipitated in about a week and formed a fluffy layer about three-fourths inch thick on the filter paper. After a period of several weeks molds developed abundantly in this deposit and some became coated with a thick brown deposit. The precipitate probably consisted chiefly of a mixture of basic ferric acetate with some ferric hydroxide. It seems likely, to judge from later experiments, that the precipitation in this experiment resulted from hydrolysis rather than from bacterial action.

The solution of iron albuminate began to ferment a day or two after it was prepared. It gradually became black and a thick brown scum formed on the surface. The changes probably resulted from complex processes of decomposition due to the presence of albumin.

No precipitation occurred in the solutions of manganese salts, but molds developed abundantly. In the manganese citrate solution mold mycelia developed as black filaments forming a matting below a light-brown brittle surface film. This growth eventually dropped to the bottom and formed a dark-gray deposit on the filter paper. Besides mold mycelia this deposit was found to contain filaments of algae and protozoa. In the manganese acetate solution the mold grew as a white, woolly matting on the filter paper. The deposit gradually became darker and more compact. The solution remained clear in both experiments.

The results in general showed that precipitation of ferric hydroxide and basic ferric salts took place in solutions of other organic iron salts besides ferric ammonium citrate but that the time and manner of precipitation varied in different solutions. They also showed that manganese was not precipitated from solution in the same manner as iron, although microorganisms developed abundantly in solutions of organic manganese salts.

It now became necessary to determine whether the precipitation from these iron solutions was due to chemical action or to the activity of organisms. For this purpose another set of solutions was prepared in the same way as the set just described except that iron albuminate was omitted. After inoculation with soil the cultures were sterilized in an autoclave. The sterilization produced a slight change of color in some of the solutions, and in the iron acetate solution it caused the formation of a reddish-brown flocculent precipitate due to hydrolysis. This precipitate probably consisted mainly of basic ferric acetates and appeared to be similar to that formed in the iron-acetate culture already described. The solutions were allowed to stand for six weeks at room temperature, and during this period did not alter their appearance. At the end of six weeks the solutions were reinoculated by adding 1 cubic centimeter of fresh soil infusion to each, and were allowed to stand under the same conditions as before for another period of six weeks.

Precipitation in the ferric ammonium citrate solution took place in about one week after the inoculation, but in the other solutions the precipitation was slower. At the end of six weeks, however, precipitates had formed in all the iron solutions, and molds were growing in the manganese solutions. The precipitate from the ferric citrate solution was flocculent and brownish yellow in color and formed a coating over the layer of soil. The precipitates from the other iron solutions (iron lactate, ferric oxalate, and ferric ammonium citrate) were very similar to those which occurred in the previous cultures that had not undergone sterilization. In general they formed brown, flocculent deposits.

After obtaining precipitates from solutions containing organic iron inoculated with soil, under different conditions as described above, several attempts were made to obtain precipitates from solutions of these salts in natural waters. However, no precipitation occurred, although some of the cultures were allowed to stand for six months at room temperature. At the end of this period only a slight turbidity was noticeable in some of them.

Attempts to isolate bacteria which might cause precipitation of ferric hydroxide or insoluble basic ferric salts from ferric oxalate and iron lactate solutions were also unsuccessful. Pure cultures of bacteria obtained from agar containing ferric ammonium citrate were transferred to slopes of Heyden Nährstoff agar containing ferric oxalate and iron lactate, but no growth took place. Later plates of the same agar and also of plain bouillon agar were inoculated directly with a fresh infusion of soil, but no colonies either of bacteria or molds formed on the plates, although plates of agar containing ferric ammonium citrate that were inoculated at the same time from the same soil infusion showed abundant growth. Whether this experiment indicates that bacteria do not grow in the presence of ferric oxalate and iron lactate and that the precipitation in the solutions was due to the action of molds which do not grow readily on solid media is difficult to say. It is very desirable that further work should be done along this line with other organic iron salts, such as iron tartrate, iron formate, iron butyrate, iron malate, iron ammonium tartrate, iron magnesium citrate, and others. Only in this way is it possible to determine how general is the precipitation of insoluble iron compounds from solutions of organic iron salts by microorganisms. From the experiments performed it seems reasonable to suppose that it is fairly general and that in certain cases bacteria are responsible and in other cases molds.

PRECIPITATION OF FERRIC HYDROXIDE AND BASIC FERRIC SALTS FROM SOLUTIONS CONTAINING INORGANIC IRON.

Several attempts were made to obtain, in solutions of inorganic iron salts, cultures of bacteria from soil and natural waters other than the iron thread bacteria already described. It seemed possible that *Siderocapsa*, described by Molisch[1] as being a very abundant water bacterium, or *Bacillus M. 7*, described by Mumford,[2] might be cultivated in artificial media containing inorganic iron salts. It seemed possible also that other lower bacteria might exist in the soil or natural waters which could use constituents present in certain inorganic iron salts with the result that ferric hydroxide or basic ferric salts would be precipitated. Such a process would be analogous to that just described as occurring when ferric hydroxide or basic ferric salts are precipitated from solutions of organic iron salts through the action of microorganisms.

However, my attempts to obtain such cultures have all been unsuccessful. Although precipitation of insoluble ferric compounds occurred in nearly all the inorganic iron solutions used, this precipitation seemed to be due to oxidation and hydrolysis or to hydrolysis alone, rather than to biologic processes. A brief statement concerning the solutions used and the results obtained is given below.

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[1] Molisch, Hans, Die Eisenbakterien, pp. 11–14, 1910.

[2] Mumford, E. M., A new iron bacterium: Chem. Soc. Jour., vol. 103, pp. 645–650, 1913.

The inorganic iron salts used in the experiments were ferrous sulphate ($FeSO_4.7H_2O$), ferrous ammonium sulphate ($FeSO_4(NH_4)_2SO_4.6H_2O$), ferrous carbonate ($FeCO_3$), and ferric chloride ($Fe_2Cl_6.nH_2O$). All of these solutions when allowed to stand where oxygen from the atmosphere was accessible became oxidized or hydrolyzed, forming yellow or yellowish-brown ocherous precipitates consisting either of ferric hydroxide or of a mixture of ferric hydroxide and basic ferric salts.

Attempts to make bacterial cultures in ferrous sulphate solutions were made with different strengths of solutions from very dilute to saturated. Yellowish-brown flocculent ocherous precipitates formed in all of them, and these were examined with the microscope from time to time for evidences of the presence of microorganisms. The precipitates in general had a granular appearance under the microscope, the granules being brownish yellow in color and somewhat rounded and fairly regular in size and shape. However, mixed with this granular material, many of the precipitates showed large irregular masses of a light-colored, textureless colloidal substance, resembling in appearance, though not in color, the precipitates formed in solutions containing organic iron or those formed by adding ammonium hydroxide to inorganic ferric salts, such as ferric chloride. The only organic forms found in the precipitates were scattered threads of mold mycelia, which were found in one or two of them after standing for several weeks.

It seems possible, of course, that the flocculent granular precipitate itself was the result of bacterial action, as is the flocculent, reddish-brown precipitate which forms in the organic iron solutions. However, with the inorganic iron salts sterilization apparently has no effect on the precipitating action, except that with some of them it hastens precipitation.

Montfort,[1] as has been stated (p. 9), claims that *Leptothrix* develops in solutions of ferrous sulphate, but I have not been able to identify it in my cultures. Up to the present time I have found no microorganisms with the exception of molds in any cultures prepared with inorganic iron salts except those containing ferrous bicarbonate.

The precipitation of ferric hydroxide and basic ferric salts from solutions of ferrous sulphate differed from that taking place in organic iron solutions likewise in that it was not complete. A flask containing 750 cubic centimeters of water in which were dissolved 3.5 grams of ferrous sulphate was allowed to stand under oxidizing conditions for 6 months. An abundant precipitate of yellowish-brown ocherous material formed during this period, but much ferrous sulphate remained in solution at the end of this time, as was shown by the flocculent, light-green precipitate of ferrous hydroxide ($Fe(OH)_2$), which formed upon the addition of ammonium hydroxide to the solution.

An interesting experiment was performed with solutions of ferrous ammonium sulphate inoculated with soil. Three bottles each containing a solution of 2 grams of ferric ammonium sulphate in 300 cubic centimeters of water were inoculated with 20 grams of soil. One of the bottles was left where oxygen of the atmosphere had free access to the solution, but the other two, one of which was sterilized, were attached to an apparatus generating carbon dioxide, and the solutions they contained were kept saturated with carbon dioxide. Precipitation began in the first bottle within 15 or 20 minutes after the solution was prepared, and in two or three days a deposit of yellowish-brown ocherous material covered the layer of soil and the inside of the bottle. The solutions saturated with carbon dioxide, however, showed no precipitation and no cloudiness, although they were left for several weeks connected with the apparatus that generated carbon dioxide. When they were finally disconnected, however, and the solutions became accessible to oxygen of the atmosphere a yellowish-brown, ocherous precipitate formed in a short time in both the sterilized and unsterilized solutions. This experiment showed that the precipitation of ferric hydroxide from solutions of ferrous ammonium sulphate was due to simple oxidation and hydrolysis.

Mumford describes the isolation of a bacillus from the water of the tunnels on the Bridgewater Canal, near Worsley, Lancashire, England, which is strongly charged with iron, owing to the entrance of iron-bearing colliery waters. He states that he made cultures of this organism in solutions of both ferric ammonium citrate and ferrous ammonium sulphate, and found that it precipitated ferric hydroxide in 24 to 36 hours at 37° C. The strength of the solutions used was 0.05 per cent, and they contained 0.005 per cent of peptone. He states that in both solutions the precipitation took place only under aerobic conditions and that the precipitation was complete, no iron remaining in solution. Under anaerobic conditions he found that precipitation did not take place, but that freshly precipitated ferric hydroxide was changed under these conditions to black compact bog ore.[1]

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[1] Montfort, W. F., Dry feed of chemicals in water purification: Jour. Am. Waterworks Assoc., vol. 2, pp. 200–206, 1915.

The results obtained by Mumford with ferric ammonium citrate solutions are similar to those which I have already described as obtained with various solutions containing organic iron, except that in my experiments I was able to cause the precipitation both under aerobic and anaerobic conditions. In my experiments, also, the complete precipitation required a longer period of time. The results obtained with ferrous ammonium sulphate, however, are difficult to understand, because, as I have shown, precipitation takes place in this solution under oxidizing conditions, whether organisms are present or not, whereas in the absence of oxygen precipitation apparently does not take place. It is difficult to see under what conditions Mumford conducted his experiments in order to determine that it was the organism and not simple oxidation that caused the precipitation.

Experimentation with solutions of ferrous bicarbonate is somewhat difficult, because of the difficulty of getting ferrous carbonate into solution, and because of the small amount capable of being taken into solution even under favorable conditions. It is difficult also to retain it in solution because of its susceptibility to oxidation. A common way of obtaining solutions of ferrous bicarbonate is to place iron filings in water which is kept saturated with carbon dioxide. In this manner ferrous bicarbonate may be obtained in solution up to about 0.01 per cent.[2] It is much more satisfactory, however, to work with natural iron-bearing waters. The oxidation and precipitation, however, take place very rapidly in such waters. A natural solution of ferrous bicarbonate which contained 5.0 parts per million of ferric oxide in the form of ferrous bicarbonate was left in a bottle with a rubber stopper. It soon became cloudy, and a yellowish-brown precipitate began to form in about an hour and continued forming for several days. After about 10 days only 0.2 part per million of ferric oxide remained in solution. The precipitate which formed was examined microscopically and was found to consist of light yellowish-brown semitransparent gelatinous ferric hydroxide with strands of iron thread bacteria, chiefly *Leptothrix*. The presence of the gelatinous ferric hydroxide would seem to indicate that the precipitation at least in part was due to simple oxidation. The presence of *Leptothrix* is explained by the fact that it occurred in the spring from which the water was taken.

A dilute solution of ferric chloride in natural water was allowed to stand at room temperature for several months with free access of oxygen of the atmosphere. A brownish-yellow precipitate, probably ferric hydroxide, similar to that which forms in inorganic ferrous solutions, formed in it. There was no evidence of bacterial action. This precipitate is notable, for normally upon the oxidation of ferric chloride by the addition of ammonium hydroxide a brownish-red, flocculent precipitate of ferric hydroxide forms. After two or three months apparently no ferric chloride remained in solution.

PRECIPITATION OF FERROUS SULPHIDE FROM SOLUTIONS CONTAINING IRON.

The precipitation of ferrous sulphide (FeS) from iron-bearing solutions occurs abundantly under the influence of microorganisms. It takes place under reducing conditions and usually in the presence of abundant decaying organic matter. The formation is usually due to the action of hydrogen sulphide (H_2S), formed under these conditions, on ferrous salts in solution, but may be due also in part to the reduction of iron salts of sulphurous or sulphuric acid. Ferrous sulphide may be formed in four distinct ways.[1] (1) Hydrogen sulphide is commonly produced by the decomposition of sulphur-bearing proteins in organic matter, due to the action of various decay-producing bacteria. By reaction with a ferrous salt in solution ferrous sulphide is precipitated by it. (2) Certain bacteria, commonly known as sulphate reducers, have the power, in the presence of decaying organic matter, of taking the oxygen away from sulphites, sulphates, or thiosulphates, and reducing them to sulphides. If these compounds happen to be compounds of iron, ferrous sulphide is formed directly. (3) If, however, some other sulphide, such as calcium sulphide (CaS), is formed in this manner, it may react with carbon dioxide and water to form hydrogen sulphide, according to the following reaction:[2]

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[1] Mumford, E. M., A new iron bacterium: Chem. Soc. Jour., vol. 103, pp. 645–650, 1913.

[2] Lieske, Rudolf, Beiträge zur Kenntnis der Physiologie von *Spirophyllum ferrugineum* Ellis, einen typischen Eisenbakterium: Jahrb. wiss. Botanik, Band 49, pp. 91–127, 1911.

$$CaS+CO_2+H_2O=CaCO_3+H_2S$$

The hydrogen sulphide thus formed may then react upon ferrous salts in solution, precipitating ferrous sulphide. (4) Certain bacteria, in the presence of decaying organic matter, act directly upon free sulphur, reducing it to hydrogen sulphide, which may precipitate ferrous sulphide (FeS), if iron salts are present.

Hydrogen sulphide is formed from decaying sulphur-bearing proteins, either by processes of reduction or by the splitting off of the hydrogen sulphide molecule as a hydrolytic cleavage product. The power of producing hydrogen sulphide from protein is common not only to practically all the putrefying bacteria but is possessed also by various other bacteria which use proteins as food. The formation is accelerated by the absence of oxygen, and is also favorably influenced by the presence of peptone.

The production of hydrogen sulphide from organic matter may be shown by hanging lead foil in a flask in which some organic matter is decomposing. Hydrogen sulphide will combine with lead, producing lead sulphide (PbS), which will form as a black coating on the lead foil. In solid media iron salts are used as indicators of the presence of hydrogen sulphide. Thus, 3 per cent of iron tartrate or iron saccharate in bouillon-peptone-gelatin indicates the presence of hydrogen-sulphide producers by the formation of iron-sulphide halos around the colonies.[3]

The method of the formation of hydrogen sulphide from decaying protein is not definitely known. If formed as a product of reduction it may result from special activities inherent to the protoplasm of the microorganisms or it may be due to the reducing action of other products, such as hydrogen, which microorganisms form. Where hydrogen sulphide forms as a direct cleavage product, it is supposed that the molecule was present in the protein as such and was released by bacterial action. However, the composition of protein is very imperfectly understood, and its decomposition is largely a matter of conjecture.

The reduction of sulphates, thiosulphates, and sulphites by sulphate-reducing bacteria commonly produces metallic sulphides but is usually accompanied also by the formation of considerable quantities of hydrogen sulphide. This is probably due to the fact that carbon dioxide present acts upon the metallic sulphides immediately upon their formation, producing hydrogen sulphide. A considerable number of bacteria probably have the power of reducing sulphates, among which the best known[4] are *Vibrio hydrosulfureus* and *Bacterium hydrosulfureum ponticum*, isolated from the Black Sea muds by Selinsky and Brussilowsky, *Proteus vulgaris* and *Bacillus mycoides*, shown by Nadson to reduce calcium sulphate to calcium sulphide in the presence of a limited supply of oxygen, *Spirillum desulfuricans*, proved by Beijerinck[5] to reduce sulphates energetically, and *Microspira aestuarii*, a form similar to *Spirillum desulfuricans*, isolated by Van Delden. Of these organisms the first two besides reducing sulphates also reduce thiosulphates when no organic sulphur is present, and the last two, one of which (*Spirillum desulfuricans*) is a fresh-water form and the other a salt-water form, reduce sulphates, thiosulphates, and sulphites. Another organism, *Bacterium sulfureum*, has been found which reduces sodium thiosulphate. Judging from the fact that some of the sulphate-reducing organisms work more effectively in the absence of organic sulphur compounds, such as proteins, it appears that many of them are capable of decomposing organic sulphur compounds as well as of reducing sulphides.

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[1] Omelianski, W., Der Kreislauf des Schwefels, in F. Lafar's Handbuch der Technischen Mycologie, Band 3, pp. 214–220, 1904–1906.

Lipman, J. G., Microbiology of soil, in Marshall's Microbiology, pp. 288–290, 1912.

Phelps, E. B., Microbiology of sewage, in Marshall's Microbiology, pp. 217–218, 1912.

[2] Lipman, J. G., op. cit., p. 290.

[3] Omelianski, W., op. cit., pp. 214–216.

[4] Idem, pp. 216–218.

[5] Beijerinck, M., *Spirillum desulphuricans:* Centralbl. Bakteriologie, Abt. 2, Band 1, p. 1, 1895.

Thiosulphates and sulphites, according to Beijerinck, are reduced also when added to fermenting sugar solution or other yeast cultures, showing that yeasts as well as bacteria have the power of sulphate reduction.

Brussilowsky[1] isolated three varieties of bacteria which are chiefly concerned in the reducing processes characteristic of the black ferrous sulphide-bearing muds of limans. These grew on meat-peptone-agar and produced the characteristic odor of the liman mud. The principal one isolated was *Vibrio hydrosulfureus*. When oxidized gray liman mud in which this organism occurs was sterilized it was found to keep indefinitely, but upon inoculation with pure cultures it showed reduction and again turned black. A great many other anaerobic bacteria probably have the same power, the functions not being confined to a few species.

An artificial medium for sulphate-reducing organisms was prepared by Brussilowsky by mixing a 2 per cent solution of aluminum chloride ($AlCl_3$) with a little ferric chloride and a little of a 0.33 per cent solution of thiosulphate, and adding ammonium hydroxide to make it alkaline. This, when inoculated with a bouillon culture of the bacteria, showed ferrous sulphide formation in 24 hours.

Nadson produced a reduction of sulphates with *Baccilus mycoides* and *Proteus vulgaris*, under anaerobic conditions and in the presence of peptone.

Beijerinck prepared cultures of sulphate reducers by using a medium consisting of ordinary ditch water and a small quantity of mineral salts, such as sodium carbonate, calcium, or magnesium sulphate, and ferrous ammonium sulphate, and traces of organic compounds such as sodium malate or asparagin. He found that small quantities of organic compounds were necessary in order to supply carbon for the organism. Impure cultures in the absence of oxygen and at a temperature of 25° to 30° C. showed reduction of sulphate, accompanied by the formation of an appreciable amount of hydrogen sulphide in 12 to 24 hours. Pure cultures of *Spirillum desulfuricans* were obtained by him on plates of agar and gelatin prepared with the above medium. The organism isolated is a slightly coiled *Spirillum* about 4 micra in length and 1 micron in thickness.

Microspira aestuarii was isolated later from salt water by Van Delden. Its close resemblance to *Spirillum desulfuricans* led to the belief that it might be the same form living under different conditions. The addition of gradually increasing quantities of common salt to the culture solutions, however, was found to have entirely different effects on the two organisms:

It was found that in pure cultures of these two microorganisms the amount of hydrogen sulphide formed was very large, amounting to several hundred milligrams per liter of culture solution. Pure cultures also thrive and react on sulphates in the presence of a larger percentage of organic material, such as bouillon, than impure cultures, because there is no competition with ordinary putrefying bacteria, which otherwise crowd out the sulphate reducers.

A good medium to use for the detection and isolation of sulphate reducers is the one used by Prof. E. B. Fred, of the University of Wisconsin, for class work, as follows:

Culture solution for sulphate-reducing bacteria.

Water	liter	1
Ammonium sulphate ($(NH_4)_2SO_4$)	grams	2
Sodium lactate	do	5
Dibasic potassium phosphate (K_2HPO_4)	do	.5
Ferrous sulphate ($FeSO_4$)		Trace.

This medium may be placed in bottles and to it should be added a small amount of garden soil (1 gram) or of marsh slime (0.1 cubic centimeter). The bottles should be filled with the medium and then corked and rendered airtight by immersing the mouth and stopper in hot paraffin. Upon incubating at 37° C. for three or four days a blackening of the solution takes place, owing to the formation of ferrous sulphide by the reduction of the sulphates present. After a period of several weeks the solution may be tested for sulphates by adding a little barium chloride ($BaCl_2$) to a small amount of the liquid culture poured into a test tube. If sulphates are still present a white precipitate of barium sulphate ($BaSO_4$) forms. In time all the sulphates present will be reduced.

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[1] Omeliansk1, W., op. cit., pp. 220–224.

Pure cultures of the organisms may be obtained by using an agar medium. This is prepared by adding 15 grams of agar to 1 liter of the liquid medium described above. The sulphate agar medium may be inoculated from the bottle cultures. After incubating for a few days colonies with black halos will develop. Organisms from these colonies may then be reinoculated into sterile liquid media or on to other plates and pure cultures thus obtained.

The following medium developed by Fred was found to be very satisfactory for obtaining cultures of sulphate-reducing organisms:

Culture medium for sulphate-reducing bacteria.

Iron lactate ($Fe(C_3H_5O_3)_2 3H_2O$)	grams	5.0
Ammonium sulphate ($(NH_4)_2SO_4$)	do	2.0
Dibasic potassium phosphate (K_2HPO_4)	do	.5
Distilled water	cubic centimeters	1,000

A solid medium may be prepared with this solution by adding it to a 15 per cent bouillon gelatin and sterilizing in an autoclave at 10 pounds pressure for 15 minutes. Colonies of sulphate-reducing bacteria growing on plates prepared from this medium will develop the characteristic dark halo due to the formation of ferrous sulphide.

The physiology of sulphate-reducing bacteria is not yet thoroughly understood. Some investigators have claimed that the reducing action is not a property of any particular species of bacteria but that it is due to nascent hydrogen, which is liberated by many anaerobic organisms. Others believe that the action is due to methane liberated during the fermentation of cellulose by certain groups of organisms, the reaction being

$$CH_4+MSO_4=MCO_3+H_2S+H_2O$$

Beijerinck rejects these explanations and cites a number of experiments in which hydrogen or methane producing bacteria did not reduce sulphates and in which sulphate reducers did not reduce other substances, such as nitrates. This indicates that the property of reducing sulphates is a special characteristic of certain bacteria, which use the oxygen taken from the sulphates for the production of energy within their cells by the oxidation of carbon to carbon dioxide. The reaction may be as follows:

$$MSO_4+2C=2CO_2+MS$$

The sulphide may then be acted upon by carbon dioxide and water, and the production of hydrogen sulphide results according to the following equation:

$$MS+CO_2+H_2O=H_2S+MCO_3$$

It is claimed that hydrogen sulphide is also produced by bacteria by the reduction of free sulphur in the presence of organic matter.[1] It was noticed that sulphur present in cultures containing decomposing organic matter gradually disappeared and that hydrogen sulphide, or, if iron salts were present, ferrous sulphide, formed abundantly. Thus Winogradsky found that the sulphur granules of dead cells of sulphur bacteria, such as *Beggiatoa*, gradually disappeared during decomposition with the formation of hydrogen sulphide. Later it was found that flowers of sulphur were attacked under the same conditions and that hydrogen sulphide was formed abundantly.

Beijerinck prepared two flasks with meat bouillon containing 1 per cent iron lactate as indicator. The oxygen present was removed by boiling and then flowers of sulphur were added to one of them. After inoculation with impure bacterial cultures and incubation for 24 hours both solutions became black through the formation of ferrous sulphide, but though the ferrous sulphide formation in the flask containing no free sulphur soon reached a limit that in the other flask continued for a long time and a large quantity of the black precipitate was formed. The formation of hydrogen sulphide from free sulphur is believed to be a secondary process, resulting from the various reactions which take place in decomposing organic matter.

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[1] Omelianski, W., op. cit., pp. 219, 220.

Associated with the hydrogen sulphide forming and the sulphate-reducing bacteria is an important and very interesting group of organisms known as the *Thiobacteria* or sulphur bacteria. A considerable number of morphologically different varieties of bacteria belong to this group, the principal members being the colorless varieties *Thiothrix* and *Beggiatoa* and the red or violet-colored varieties known collectively as *Rhodobacteria.* The sulphur bacteria have the power of oxidizing hydrogen sulphide to free sulphur and sulphuric acid, thus obtaining energy for the assimilation of food. The sulphuric acid formed immediately unites with bases present to form sulphates. The food of these bacteria is derived from organic matter, while the oxygen necessary for the oxidation of hydrogen sulphide is derived from free oxygen dissolved in the water.

As sulphur bacteria require both hydrogen sulphide and oxygen, and as an increase in hydrogen sulphide in solution results in an expulsion of oxygen, there is a certain horizon in the solution where the oxygen, which comes down from the surface, and the hydrogen sulphide, which comes up from the decaying organic matter on the bottom, are both present in the right proportions for these organisms to thrive on. At this horizon they form a platelike film, and it is below this film that sulphate-reducing and hydrogen sulphide forming bacteria are most active.

Jegunow[1] found that in limans (see p. 63), where the water is shallow and the mud is grayish and slightly oxidized, the sulphur bacteria lie on the bottom. With increasing depth and decrease of oxygen, the sulphur bacteria are forced to leave the bottom and form a thin layer through the water, while the mud becomes black in consequence. He believes that such a layer of bacteria is probably found over the entire Black Sea at a depth of about 200 meters.

Laboratory cultures made of black liman muds in water in a high glass jar showed a cloudy platelike swarm of organisms 0.2 to 0.3 millimeter thick in the water. The height of this layer above the mud depended on the amount of hydrogen sulphide formed. When it sank down to the mud the mud became gray through oxidation, but upon the exclusion of oxygen it again became black and the swarm layer rose in the water.

The sulphates formed abundantly by the sulphur bacteria from hydrogen sulphide are attacked by the associated sulphate-reducing bacteria and are again reduced to sulphides and hydrogen sulphide, thus making a complete cycle. If ferrous or manganese sulphide are formed, they are precipitated.

GEOLOGIC IMPORTANCE OF IRON-DEPOSITING BACTERIA.

IRON IN THE EARTH'S CRUST.

In a study of the deposition of sedimentary iron-ore deposits there are four important points to consider: (1) The source and the manner of solution of iron compounds, (2) the transportation of iron compounds, (3) the manner of deposition of iron compounds, and (4) the conditions under which iron compounds are deposited.

Iron is abundant in the earth's crust in both the ferrous and ferric forms. Ferrous iron occurs in nearly all rocks. In the original crystalline rocks, such as granite, diorite, gabbro, pyroxenite, and peridotite, ferrous iron forms an important constituent of the ferromagnesian silicates, mainly biotite, amphibole, pyroxene, olivine, and chlorite. It is also present in the oxides of iron, magnetite and ilmenite, which form a noticeable percentage of the more basic crystalline rocks. In sedimentary rocks ferrous iron is present in original undecomposed silicates that occur in shales and graywacke, in secondary silicates, and also in secondary iron carbonate, which occurs in varying abundance in nearly all sedimentary rocks. In metamorphic rocks ferrous iron occurs mainly in the secondary iron silicates, especially in biotite, amphibole, chlorite, and garnet, but to some extent it is also present as recrystallized iron carbonate.

Ferric iron occurs in original crystalline rocks, mainly as the oxides magnetite, hematite, and ilmenite, but it is also found in smaller amounts in some of the silicates, such as biotite, amphibole, pyroxene, and epidote.

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[1] Jegunow, M., Bakterien-Gesellschaften: Centralbl. Bakteriologie, Abt. 2, Band 2, p. 20, 1896.

In sedimentary rocks it is found mainly as the oxides hematite and limonite, and in some iron silicates, such as glauconite, and in metamorphosed sediments it occurs as the oxides hematite and magnetite and in the silicates biotite, amphibole, and garnet.

In addition to these minerals, iron is present in nearly all rocks in the form of the sulphides pyrite or marcasite, and occasionally in basic igneous rocks as pyrrhotite.

Thus iron is one of the most abundant and widely distributed metals on the surface of the earth, the only metal exceeding it in abundance being aluminum. In Clarke's average analysis of the earth's crust to a depth of 10 miles,[1] ferrous and ferric oxide, considered together, rank third in abundance of all the oxides, being exceeded only by silica and alumina. The principal constituents in the average rock and in the average igneous rock as given by Clarke, rank as follows:

Composition of average rock of the earth's crust and of average igneous rock.

	Average rock.[a]	Average igneous rock.
SiO_2	59.77	59.83
Al_2O_3	14.89	14.98
CaO	4.86	4.84
MgO	3.74	3.81
FeO	3.39	3.46
Na_2O	3.25	3.36
K_2O	2.98	2.99
Fe_2O_3	2.69	2.65
H_2O	2.02	1.89
All other constituents	2.41	2.19
	100.00	100.00

[a] In the average rock which, according to Clarke, represents the earth's crust to a depth of 10 miles, the following percentages of igneous and sedimentary rocks are taken: Igneous, 95 per cent; shale, 4 per cent; sandstone, 0.75 per cent; limestone, 0.25 per cent.

DECOMPOSITION OF IRON-BEARING MINERALS.

When the rocks forming the earth's crust suffer disintegration and decomposition in their change to soil the iron compounds are dissolved by the action of the acids that are present in surface and ground waters. These acids are principally carbonic acid (H_2CO_3) and various organic acids, such as butyric, propionic, formic, lactic, acetic, citric, tartaric, valerianic, and the little-known humic acids. Van Hise[2] mentions the common occurrence in the soil of certain other organic acids, such as crenic, apocrenic, and ulmic acids. Inorganic acids are present in the soil in small quantities and occur more or less locally. The principal ones probably are nitrous, nitric, sulphuric, and perhaps hydrochloric. Phosphoric and silicic acids also are present, but they are not important in processes of rock decay.

The presence of these gases and acids in the soil results from two conditions: First, and most important, is the decay of organic matter, due to bacterial action, and, second, is the decomposition of inorganic material, due to chemical agencies, which in part also owe their origin to bacterial action.

Carbon dioxide, which is the most important of these agents in the process of rock decay, is in part derived from the decomposition of carbonates, due to the action of acids, but mainly it is derived from the decay of organic carbon compounds under the action of various fermenting and decay-producing microorganisms, such as bacteria, yeasts, and molds.

The carbon in animals and plants may be in the form of carbohydrates, fats, or proteins. Carbohydrates, in which form by far the most carbon occurs in nature, are decomposed to carbon dioxide and water by the action of certain hydrolytic enzymes, commonly produced by various organisms, the decomposition taking place in a series of steps as is shown by the following formulae, which illustrate acetic fermentation as an example. Decomposition to other fatty acids, such as lactic, tartaric, and butyric, goes on along similar lines.

$$\overset{\text{(Starch.)}}{2C_6H_{10}O_5} + H_2O = \overset{\text{(Double sugar.)}}{C_{12}H_{22}O_{11}}$$

$$C_{12}H_{22}O_{11} + H_2O = \overset{\text{(Single sugars.)}}{C_6H_{12}O_6 + C_6H_{12}O_6}$$

$$C_6H_{12}O_6 = \overset{\text{(Alcohol.)}}{2C_2H_5OH} + 2CO_2$$

$$C_2H_5OH + O = \overset{\text{(Acetic aldehyde.)}}{C_2H_4O} + H_2O$$

$$C_2H_4O + O = \overset{\text{(Acetic acid.)}}{C_2H_4O_2}$$

$$C_2H_4O_2 + 4O = 2CO_2 + 2H_2O$$

The change from starch to the double sugars, maltose, saccharose, or lactose, is due to the action of the enzyme diastase produced by all green plants, many molds, and a few bacteria. The decomposition from double sugars to single sugars is due to the action of the enzymes maltase, invertase, and lactase, each acting on a special sugar. These three enzymes differ in distribution but in general are present in green plants and in various microorganisms. Single sugars are acted upon directly by fermenting enzymes, the change to alcohol being due mainly to the action of yeasts, and the further decomposition of alcohol to fatty acids and carbon dioxide taking place under the action of bacteria and molds. The principal acids formed in this manner in the soil are butyric, propionic, acetic, formic, and lactic acids. The end products of the fermentation are large quantities of carbon dioxide and water.

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[1] Clarke, F. W., The data of geochemistry, 3d ed.: U. S. Geol. Survey Bull. 616, p. 32, 1916.

[2] Van Hise, C. R., A treatise on metamorphism: U. S. Geol. Survey Mon. 47, pp. 461–462, 1904.

Though these changes are the typical ones through which most carbohydrates pass in the process of decomposition, many irregularities and variations occur. Cellulose, for example, which is probably the most abundant carbohydrate in the soil, is decomposed by a special group of microorganisms known as cellulose fermenters. During the decomposition it may be changed directly to fatty acids, or it may be changed first to sugar and then to different gases, such as methane, hydrogen, and carbon dioxide.

The carbon in fats and proteins also suffers the change to fatty acids and carbon dioxide. The decomposition of the proteins, however, is very complex, and many little known compounds, including those of nitrogen, sulphur, and phosphorus, are formed during the process.

The carbonaceous material that resists decomposition by fermenting and decay-producing microorganisms collects in the soil in the form of humus. Humus consists mainly of cellulose, which is the most difficult of the different forms of organic carbon to decompose. The further decomposition of humus goes on very gradually, and during the process the different gases and organic acids already mentioned are produced, as well as humic acids. The composition of humic acids is not well understood, but it is now supposed that they are colloidal mixtures of various complex organic acids or of their acid salts.[1] Humus, therefore, acts as a constant source of soil acids and gases. Humic acids and their acid salts (humates) may be so abundant as to cause acidity of the soil in places where bases are not present in sufficient quantity to neutralize the acids produced.

Inorganic acids in the soil are in part derived from the decomposition of certain minerals, such as sulphides, sulphates, and chlorides, and when so derived are local in their occurrence. Nitrous and sulphuric acids, however, are produced also during certain very important soil processes known as nitrification and sulphur oxidation.

The nitrogen content of proteins, urea, and other nitrogenous organic compounds is changed during decomposition by ammonifying bacteria into the form of ammonia (NH_3). The ammonia is acted upon by nitrifying bacteria, and the nitrogen is oxidized first to the nitrous and then to the nitric form. During the first part of the process nitrous acid is formed from ammonia, and this immediately reacts upon bases present in the soil to form nitrites, which are then oxidized to nitrates. Thus the nitrogen, and the bases with which it combines, were first present in a relatively insoluble form and have been changed by bacterial action to soluble nitrates, in this manner hastening rock decomposition.

Sulphur oxidation in general is very similar to nitrification. During the putrefaction and decay of sulphur-containing organic matter by ordinary putrefying bacteria, sulphur is liberated in the form of hydrogen sulphide (H_2S). This gas is oxidized by a special group of bacteria, the sulphur bacteria, first into free sulphur and then into sulphuric acid. The sulphuric acid immediately reacts upon the bases present to form sulphates, which for the most part are more or less soluble.

Thus it is clear that processes of bacterial decomposition are of unusual importance in promoting rock decay. They not only result in the formation of most of the carbon dioxide produced in the soil but also of many organic and a few inorganic acids, which locally become of importance in promoting decomposition.

By far the most abundant of the acids in the soil is carbonic acid or carbon dioxide. Although relatively weak, its abundance and continued action cause most metals, including iron, to be taken into solution in the form of carbonates. Nearly all ferrous compounds, but especially ferrous carbonate, are readily acted upon by carbonic acid dissolved in meteoric water, are taken into solution in the form of carbonate or bicarbonate, and are carried thus as long as the waters contain an excess of carbon dioxide in solution. Moody[1] says that carbonic acid exerts a greater corrosive influence on iron than equivalent amounts of hydrochloric or sulphuric acids. Some compounds of iron, however, especially ferric oxide, are practically insoluble in waters that carry only carbon dioxide, and in the solution of these compounds various other soil acids and decaying organic matter become effective. There is little doubt, therefore, that all iron compounds, even the most insoluble, such as ferric oxide, are acted upon to some extent by soil waters, especially if decaying organic matter is present. The intensity of the action differs in different places according to the composition of the water, and this depends more or less upon the character of the soil or rocks through which the water passes and upon the presence of vegetation. The influence of rock composition is well illustrated by certain rocks which are rich in ferric oxide and contain locally particles or bunches of sulphide of iron. In the neighborhood of the decomposing iron sulphide the ferric oxide is commonly reduced, by the liberated sulphuric acid, to the ferrous form, which is indicated by a change in color from yellow or red to white or green. The influence of vegetation is shown in some bog limonite deposits, where in places near abundant decomposing organic matter, such as rotting logs, the yellow bog scum is often bleached to a white or green color. This reduction is probably in part due to organic acids, which are abundant under these conditions, and in part to the action of decomposing organic matter, which requires oxygen and takes some of it from the ferric oxide. Kindler,[2] as early as 1836, called attention to the fact that decaying vegetable matter has a marked effect on the solubility of ferric hydroxide. He noticed that ferruginous quartzose sand was rendered colorless around decaying roots and in a few months became as white as if it had been treated by an acid. A root one-sixth of an inch in diameter, upon decaying, whitened the sand to a distance of 1 to 2 inches around it. This action is ascribed to organic acids produced during the decay. Ferric hydroxides are in this manner reduced to the protoxide, which at the same time combines with carbon dioxide to form carbonate. Iron carbonate becomes soluble and remains in solution in the presence of excess carbon dioxide.

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[1] Lipman, J. G., Microbiology of soil, in Marshall's Microbiology, p. 260, 1912.

The decomposition of iron sulphides, which is caused principally by partial oxidation, probably results in the formation of soluble ferrous and ferric sulphates. These sulphates may be carried in solution for some time if conditions are favorable. They are not very stable, however, and upon further oxidation and hydrolysis for the ferrous or simple hydrolysis for the ferric sulphate, they readily change to ferric hydroxide or to insoluble basic ferric sulphates.

According to the extent to which organic acids are present iron may be carried in solution as salts of these acids. It is not impossible that such organic salts as iron formate, iron butyrate, iron lactate, or iron citrate may occur in iron-bearing waters. Aschan[3] is of the opinion that great quantities of iron are carried in solution as soluble ferrohumates and ferrihumates and that humus compounds are largely instrumental in the formation of bog iron ore deposits, being active both in the solution of iron compounds and in their subsequent precipitation. He believes that the dark color of streams that pass through regions of abundant vegetation is largely due to the presence of humus compounds.

Once the iron is reduced to a form in which it is soluble in water it may be taken into solution and carried a greater or less distance depending upon the change in composition suffered by the water. It is generally supposed, probably with sufficient reason, that iron is carried in solution mainly as ferrous bicarbonate and is kept in solution as long as the waters retain an abundance of carbon dioxide. Among the iron-bearing waters analyzed many have been found which contain no sulphate or other acid radicle besides the carbonate, thus showing conclusively that at least in these waters iron was carried as the soluble carbonate. It is quite possible, however, that iron is carried to some extent also in other forms, perhaps as ferrous or ferric sulphate or as compounds of some of the organic acids.

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[1] Moody, G. T., The rusting of iron: Chem. Soc. Jour., vol. 89, pp. 720 et seq., 1906.

[2] Poggendorff's Annalen, Band 37, p. 203, 1836.

[3] Aschan, Ossian, Die Bedeutung der wasserlöslichen Humusstoffe für die Bildung der See und Sumpferze: Zeitschr. prakt. Geologie, Jahrg. 15, p. 56, 1907.

The waters of many streams, springs, and lakes contain much iron in solution, as has been shown by analysis, by the fact that flocculent precipitates of ferric hydroxides occur in them, that iridescent films of limonite form on their surface, and by the fact that objects with which they come in contact commonly become coated with limonite. Thus, although it is undoubtedly true that ferric oxide, which is soluble with great difficulty, forms in abundance by the oxidation of other iron compounds and along with alumina and other insoluble substances becomes concentrated in residual soils, still it is certain that acids capable of taking and retaining iron salts in solution are abundantly present in soil waters and a large amount of iron is undoubtedly carried away by surface waters and redeposited elsewhere.

TYPES OF SEDIMENTARY IRON ORES AND IRON FORMATIONS.

GENERAL FEATURES.

Iron may be precipitated from natural solutions under ordinary conditions of sedimentation either by chemical or by biologic agencies. The precipitates may occur in any one of the following forms: Ferric hydroxides, ferrous carbonate, hydrous ferrous and ferric silicates of several kinds, iron phosphates, basic ferric sulphates, ferrous sulphide, and perhaps iron disulphide.

In the formation and accumulation of deposits of ferric hydroxide biologic agencies play a most important part, though chemical action is undoubtedly of great importance as well. Iron sulphide also may be formed either chemically or by the action of microorganisms. Ferrous carbonate and iron silicates, however, are not definitely known to be precipitated by organisms. They are probably chemical precipitates, the presence of organic matter being commonly an important factor in their formation. Iron phosphates and basic ferric sulphates are chemical precipitates.

Iron may be precipitated under many conditions. Usually it is taken into solution by ground waters that contain carbon dioxide in their passage through soil and rock, and in general it remains in solution as long as the water retains an excess of carbon dioxide. Under ordinary conditions ground waters lose their carbon dioxide and become saturated with oxygen soon after they reach the surface, and the iron is deposited as ferric hydroxide. Iron bacteria are nearly always present under these conditions and not only aid in the precipitation but play an important part in the accumulation of the precipitated material. If the iron-bearing waters reach the surface in localities where abundant vegetation and decaying organic matter are present they may not become saturated with oxygen, but the solvent carbon dioxide may be taken up by the growing plants. In such localities the iron is precipitated as ferrous carbonate. If alkaline silicates are abundant in the water ferrous silicates may be formed. If phosphorus is present it is usually precipitated with the iron.

In localities where conditions are such that the iron is not chemically oxidized, when the iron-bearing waters come to the surface and when carbon dioxide is formed in sufficient abundance to retain the iron in solution, iron bacteria may be the agency in precipitation. Such conditions probably exist to some extent also in larger underground openings, such as caves and fissures, and under these circumstances certain subsurface concentration deposits of brown iron ore may be formed. When iron is carried in solution in the form of soluble humates or other salts of organic acids, iron-precipitating bacteria may also play an important part in its deposition.

The accumulation of iron precipitates usually takes place in quiet waters, such as bogs, marshes, lakes, and lagoons. Often, however, deposition occurs where iron-bearing waters issue from the ground and where they usually flow quite rapidly in little streams and rivulets. Some of the iron precipitated under this condition is doubtless carried along mechanically as little flocculent masses and is finally deposited in quiet water, where it may accumulate. Much of it, however, is doubtless lost in the mass of other sediments, so that only a relatively small proportion of the iron dissolved and carried in solution by ground waters is actually accumulated in the form of iron-ore deposits.

Sedimentary iron ores and iron ores derived directly from iron-bearing sediments by concentration are of great importance commercially. Deposits of this nature occur on nearly all the continents, and probably more than 90 per cent of the iron ore that is being produced at the present time is of this type. Such ores consist of hematite, limonite, or iron carbonate, the first two being by far the most important.

DEPOSITS ORIGINALLY LAID DOWN MAINLY AS FERRIC HYDROXIDE.

Ferric hydroxides or hydrated ferric oxides are probably the most important iron compounds that play a part in processes of sedimentation. The following table shows the composition of anhydrous ferric oxide and of the ferric hydroxides which are known to occur in nature:

Chemical composition of ferric oxide and the ferric hydroxides that occur in nature.

	Fe	O	H_2O
Hematite (Fe_2O_3)	70.0	30.0	0.0
Turgite ($2Fe_2O_3.H_2O$)	66.3	28.4	5.3
Goethite ($Fe_2O_3.H_2O$)	62.9	27.0	10.1
Limonite ($2Fe_2O_3.3H_2O$)	59.8	25.7	14.5
Xanthosiderite ($Fe_2O_3.2H_2O$)	57.1	24.5	18.4
Limnite ($Fe_2O_3.3H_2O$)	52.3	22.4	25.3

Most of the deposits of bedded hematite, as well as deposits of bog ore and beds of brown iron ore, were probably originally laid down in the form of limonite, associated with other ferric hydroxides and ferrous carbonate and locally accompanied by minor quantities of other iron compounds, such as phosphate, silicates, or sulphide. The ferric hydroxides that are probably most abundantly associated with limonite in freshly deposited iron sediments are xanthosiderite and limnite, both of which have been found in bog ores of recent origin which also carry impurities such as organic acids, phosphoric acid, and clastic material. In older iron-ore beds the hydroxides that contain less water appear to be more commonly associated with limonite, and in many of them only slightly hydrated hematite is the most important constituent. Deposits which are composed mainly of a mixture of various ferric hydroxides are commonly known as limonite or brown iron ore deposits.

Hematite and limonite of sedimentary origin are distributed in many parts of the world, and one or both of them occur in many important iron-ore deposits and iron-bearing formations. Among deposits which are formed wholly or in part by ferric oxide or hydroxide of original sedimentary origin are the Clinton hematite beds of the eastern United States, the Wabana iron-ore beds of Newfoundland, the iron-bearing formation of the Lake Superior region, the hematitic quartzite and associated bedded hematite of Minas Geraes, Brazil, the banded jasper and associated hematite of India, the extensive Jurassic oolitic limonite ores of Lorraine and Luxembourg, and the widely distributed bog and lake ores.

Beds and lenses of iron ore of Clinton (Silurian) age occur in many parts of the Appalachian region in eastern United States, extending from New York as far south as Alabama.[1] The ores are interbedded with shale and sandstone. In some places only one bed is found, but in other places three or four beds occur one above the other and separated from each other by clastic sediments. In many places lenses of clastic material occur within iron-ore beds. The iron-ore layers themselves range in thickness from a few inches to 40 feet, and single beds may extend along the strike of the rocks for many miles. As most of them occur in a region of folded rocks they have attitudes ranging from horizontal to vertical.

The Clinton ore beds are composed principally of three classes of ore—(1) oolitic, (2) fossil, and (3) finely granular or textureless ore. By far the larger part of the ore beds is formed by oolites, but locally fossils are very abundant in the ore beds, and in places may even form the principal part of them. Finely granular material is nearly everywhere present in small amount, and in places forms definite lenses within the oolitic or fossiliferous material. Locally ferruginous pebbles occur near the base of the ore beds.

The ore is mainly ferric oxide and contains calcium carbonate and silica as impurities.

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[1] Burchard, E. F., Butts, Charles, and Eckel, E. C., Iron ores, fuels, and fluxes of the Birmingham district, Ala.: U. S. Geol. Survey Bull. 400, 1910.

Burchard, E. F., Preliminary report on the red iron ores of east Tennessee, northeast Alabama, and northwest Georgia: U. S. Geol. Survey Bull. 540, pp. 279–328, 1914; The red iron ores of Tennessee: Tennessee Geol. Survey Bull. 16, 1913.

Newland, D. H., and Hartnagel, C. A., Iron ores of the Clinton formation in New York: New York State Mus. Bull. 123, 1908.

The water content of the hard ore which has not suffered surface weathering is remarkably low, being on the average only about 0.5 per cent. Even in the weathered surface ore the water content averages only from 2 to 3 per cent. Roughly the composition of the hard unweathered ore is as follows:

Composition of hard unweathered Clinton iron ore.

Fe_2O_3	52
$CaCO_3$	34
SiO_2	10
Al_2O_3	3.5
H_2O	.5

Upon weathering the calcium carbonate is removed, causing a proportionate increase of the remaining constituents and commonly increasing the ferric oxide content to 70 per cent. There is an increase in water in the weathered ore because of hydration.

The spherules in the Clinton oolitic ore on being examined microscopically are seen to consist of a nucleus of quartz or shell fragment around which are concentric alternate layers of hematite and silica or of hematite and calcite. Many spherules contain a green mineral, supposed to be an iron silicate, in the center. The matrix separating the spherules is largely calcite and detrital quartz.

Three principal hypotheses have been offered for the origin of the Clinton iron ore. The one most generally accepted is that the beds were originally laid down, together with the inclosing rocks, in much the same form in which they now occur.[1] The iron is supposed to have been precipitated as ferric hydroxide and later, owing to compression, to have been dehydrated. The oolites were probably formed immediately after deposition, while the ferric hydroxide was still in a flocculent form. The replacement of much of the calcium carbonate in the fossils present is believed to have taken place during the deposition. The second hypothesis is that the present hematite layers represent original beds of limestone, which have been replaced at some later period by iron brought in by percolating waters. By this hypothesis it is difficult to explain the regularity of the beds as well as the absence of similar replacement phenomena with reference to other limestone beds in the region. According to the third hypothesis[2] the ore beds were originally laid down as glauconite, which was subsequently leached of some of its impurities and oxidized to hematite. As evidence is given the fact that unaltered remnants of a green mineral, supposed to be an iron silicate, occur in some of the spherules composing the oolitic ore.

The Wabana iron ore[3] is found in beds which outcrop on Bell Island in Conception Bay in the eastern part of Newfoundland. The beds dip northwestward underneath the waters of the bay at angles that range from 8° to 10°. Many individual beds range in thickness from mere seams to 30 feet or more. They are scattered through about 1,000 feet of strata, but they are more or less grouped into zones which are separated by zones of barren rock. The thickest one of the barren zones is 600 feet in thickness. Though the individual ore layers differ in thickness from place to place, the ore zones are very continuous. The inclosing rocks are indurated sandstones, shales, and slates of Arenig to Llandeilo age (Ordovician).

The principal ore mineral is hematite, with which chamosite, an aluminous ferrous silicate, is abundantly associated. Siderite forms a considerable proportion of the ore beds locally and quartz occurs as detrital fragments. Fossil fragments of shells, mainly brachiopods, consisting of calcium phosphate, occur throughout the ore and tubes of boring algae are very abundant.

The great mass of the ore has an oolitic texture, being composed of fine spherules of mixed hematite and chamosite, generally somewhat flattened parallel to the bedding. Microscopically the individual spherules are seen to consist of alternate layers of hematite and chamosite arranged concentrically about a center which may be detrital quartz, a shell fragment, or chamosite. Locally the spherules may consist almost entirely of chamosite and elsewhere of hematite. The matrix between the spherules is generally chamosite, but hematite, quartz, or siderite may replace it in part or entirely.

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[1] Smyth, C. H., jr., On the Clinton iron ore: Am. Jour. Sci., 3d ser., vol. 43, p. 487, 1892.

[2] McCallie, S. W., Report on the fossil iron ores of Georgia: Georgia Geol. Survey Bull. 17, 1908.

[3] Hayes, A. D., Wabana iron ores of Newfoundland: Canada Geol. Survey, Dept. Mines, Mem. 78, 1915.

The range in composition of the Wabana iron ores is as follows:

Mineral composition of Wabana iron ores.

	Per cent.
Hematite	50–70
Chamosite	15–25
Siderite	0–50
Calcium phosphate	4–5
Quartz	0–10
Calcite	0–1

In contrast to the Clinton ores and to the oolitic limonite of northern France and southern Germany described later, these ores contain little or no calcium carbonate but instead contain abundant calcium phosphate.

The ores are supposed to be primary bedded deposits, originally laid down with the inclosing clastic sediments in much the same form in which they occur now, the hematite and chamosite being deposited at the same time but perhaps under slightly different conditions. The spherules are supposed to have resulted from the action of surface tension on the fine unconsolidated sediments. Boring algae presumably played an important part in the ore formation. Tubes of these organisms penetrate both spherules and matrix and seem to have thrived during the ore deposition. It is thought that they may be responsible for part of the oxidation to hematite.

In the Lake Superior region extensive beds of iron-bearing formation of pre-Cambrian age are found, interlayered with metamorphosed clastic sediments such as slate and quartzite and with volcanic flows.[1] The beds have a maximum thickness of 1,000 feet or more and in places are known to be continuous along the strike for more than 200 miles. The iron-bearing formation as exposed consists mainly of hematitic and limonitic chert and slate and iron ore. These rocks in many places grade downward at different depths along the bedding into sideritic chert and slate, or into greenalite rock, a ferrous silicate rock. Metamorphosed phases of the various types of the iron-bearing formations which have been altered by igneous intrusions or regional deformation occur locally.

The hematitic and limonitic chert and slate were probably derived mainly by oxidation from the sideritic chert and ferrous silicate rock, and the iron ore is believed to have been derived from the hematitic and limonitic chert by the leaching and removal of silica under the influence of meteoric waters. The iron-bearing formation was, therefore, for the most part laid down originally as sediments that consolidated into sideritic chert, sideritic slate, and greenalite rock. In association with these rocks, however, there were locally deposited beds and lenses of original ferric oxide or hydrated ferric oxide and silica which upon consolidation formed a rock very similar in all respects to the hematitic and limonitic chert formed by the secondary alteration of the sideritic chert and greenalite rock. In places layers of original relatively pure hematite ore are found with these beds, which in their character and manner of origin probably resemble the Clinton and Wabana iron ores.

In the State of Minas Geraes, in southeastern Brazil, there are extensive beds of so-called "itabirite," an iron oxide bearing quartzite, that contains intercalated beds and lenses of ferruginous schist and of pure hematite.[2] The itabirite in general is a thinly laminated rock that consists of alternating layers of quartz sand and iron oxide. In places, however, these two constituents are irregularly intermixed, forming a granular rock. The itabirite and associated iron ore and schist are interbedded with metamorphosed sedimentary rocks of probable pre-Cambrian age. The iron-bearing formation varies greatly in thickness, being less than 20 feet thick in some parts of the region and more than 4,000 feet thick in other parts. It is underlain by a great thickness of sericitic quartzite which in turn overlies granite and gneiss. At the contact of the iron-bearing formation and quartzite is a thin layer of argillaceous schist. Above the iron-bearing formation is a schist bed of great thickness, which in the upper part becomes quartzitic. In the lower part of this schist are local beds and lenses of limestone and itabirite. In places beds of manganese ore also occur near the contact of the iron-bearing formation and the overlying schist.

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[1] Van Hise, C. R., and Leith, C. K., The geology of the Lake Superior region: U. S. Geol. Survey Mon. 52, 1911.

[2] Leith, C. K., and Harder, E. C., The hematite ores of Brazil and a comparison with the hematite ores of Lake Superior: Econ. Geology, vol. 6, pp. 670–686, 1911.

Harder, E. C., The "itabirite" iron ores of Brazil: Econ. Geology, vol. 9, pp. 101–111, 1914.

Harder, E. C., and Chamberlin, R. T., The geology of central Minas Geraes, Brazil: Jour. Geology, vol. 23, pp. 341–378, 385–424, 1915.

The iron content of the itabirite in general ranges between 30 and 50 per cent, and the interlayered iron ores range from 50 to 70 per cent in metallic iron. In fact the itabirite, with diminishing quartz, grades into iron ore. Both hard and soft ores occur, the former being of very high grade and commonly averaging 69 to 70 per cent metallic iron and less than 0.02 per cent phosphorus for an entire deposit. High-grade hard-ore beds have a maximum thickness of 750 feet and a maximum length of 4,000 feet, but the lower grade soft ores form deposits several thousand feet in thickness and more than 2 miles in length.

The iron ores and associated itabirite and schist are believed to be primary sediments. The iron was probably deposited as ferric hydroxide by chemical and biological agencies at the same time as the associated clastic material.

The Archean rocks of British India consist of a basement of gneisses and crystalline schists. These are overlain by what is known as the Dhárwar series of metamorphosed sediments, consisting of conglomerate, quartzite, slate, phyllite, crystalline limestone, and different kinds of schist. Both of these series have suffered deformation and have been intruded by granitic and other rocks. The Dhárwar series locally contains beds of iron-bearing rocks, such as banded hematitic and magnetitic jaspers and ferruginous quartzites and schists associated with beds and lenses of pure iron ore.[1] Scattered areas of Dhárwar rocks occur in many parts of the peninsula of India, and iron-ore deposits are found in them both in the north and south.

The iron-ore deposits range in size from mere seams to great tabular lenses, some of the largest of which are 300 feet in thickness and cover many acres. The ore is generally hard and massive, but locally where associated with slate or phyllite it is soft, laminated, and schistose. It consists of a mixture of hematite and magnetite and contains as impurities quartz and chlorite or pale-green amphibole (grünerite). Some of the ore contains as much as 68 per cent metallic iron and only about 2 or 3 per cent of impurities. As silica and amphibole increase the ore grades into hematitic and magnetitic quartzite and jasper.

The ores are supposed to be original sediments that were precipitated chemically as ferric hydroxide and later metamorphosed to their present form.

Beds of siliceous iron ore and associated ferruginous rocks similar to those of Brazil and India occur in Dunderland, in the northern part of Norway.

Jurassic limonite, or "minette" ore, is of widespread distribution in northern France and southern Germany, and is of great importance commercially.[2] The ore occurs as lenticular beds interlayered with shale, sandstone, and marl of Middle Jurassic (Dogger) age, not far above the underlying Lias marls. The seven principal ore beds vary in thickness, the maximum being 20 feet, and occur within a vertical distance of 75 to 150 feet. They are separated from one another by beds of marl and limestone. The sedimentary beds are nearly horizontal but have a very gentle dip to the west, and the iron-ore layers conform in structure with the sediments.

The ore beds consist mainly of oolitic limonite, soft and earthy, different beds having different colors, such as gray, brown, red, green, and yellow. With the limonite occur some calcite, siderite, secondary magnetite, and iron silicates, mainly glauconite, but berthierine, chamosite, and thuringite also have been found. The spherules that make up the oolitic ore are about the size and shape of millet seed or smaller, and consist of ferric hydroxide with a skeleton of silica. They are cemented by silica, lime, and clay shale.

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[1] Weld, C. M., The ancient sedimentary iron ores of British India: Econ. Geology, vol. 10, pp. 435–452, 1915.

Holland, T. H., Geology of the neighborhood of Salem, Madras Presidency: Geol. Survey India Mem. 30, pt. 2, pp. 103–168, 1901.

[2] Einecke, G., and Köhler, W., Die Eisenerzvorräte des Deutschen Reiches: The iron-ore resources of the world, p. 670, Stockholm Internat. Cong. Géol., 1910.

Dondelinger, V. M., Die Minette im Grossherzogtum Luxemburg: Idem, p. 43.

Nicou, L., Les ressources de la France en minerais de fer: Idem, p. 3.

Cayeux, L., Les minerais de fer oölithique de France, 1909.

Kohlmann, W., Die Minettenablagerungen des lothringischen Jura: Stahl und Eisen, 1902, pp. 493–503; 554–570, 1273–1287, 1340–1357.

Van Werwecke, L., Bemerkung ueber die Zusammensetzung und Entstehung der lothringisch-luxemburgischen oölithischen Eisenerze: Zeitschr. prakt. Geologie, 1901, p. 396.

The oolitic limonite is of low grade and contains abundant impurities. The range in composition of ore from different beds is as follows:

Range in composition of Jurassic limonite of France and Germany.

	Per cent.
Fe	34- 40
SiO_2	7- 16
Al_2O_3	2- 8
CaO	6- 19
P	0.3-0.7
CO_2+H_2O	14- 22

Hypotheses have been offered for the origin of the Jurassic limonite similar to those advanced for the origin of the Clinton ores. It was formerly held that the ores were replacements of oolitic limestone beds, due to the action of iron-bearing waters. More recently, however, hypotheses have been advanced claiming that the ores were deposited as original iron-bearing sediments. Some investigators believe that the ore was originally deposited as oolitic siderite and that it has subsequently been oxidized in large part to limonite. Others, who have found iron silicates in the ore beds as well as silica in the ore spherules, claim that, in part at least, the ore is an alteration product of original iron silicates, perhaps glauconite. Still others hold that the beds were deposited essentially in their present form, mainly as limonite, but with admixtures of iron carbonate and iron silicates.

Bog iron ore is found in many parts of the world. It consists essentially of an earthy yellow to red or dark-brown mixture of ferric hydroxides, mainly limonite but with associated limnite and xanthosiderite. With these hydroxides occur some silicate, sulphate, and locally carbonate of iron, besides organic matter and clastic material, such as sand and clay. Bog iron ore is usually high in phosphorus, which is present as the iron phosphate, vivianite,[1] and locally wad or bog manganese also is an abundant constituent. The organic matter consists of humus substances and of plant remains, such as leaves and sticks, which may be in part or entirely replaced by limonite.

Bog iron ores are of two kinds—(1) those formed in lakes by water currents and known as lake ores,[2] and (2) those formed in place in still water and occurring either as surface layers lying on soil or below a layer of porous surface soil and resting on clayey impervious subsoil.

Lake ores have been described from localities in Ontario and Quebec in Canada and from the eastern United States, as well as from Sweden and other places in northern Europe. The Canadian deposits, which are typical, consist mainly of layers of flat disklike or irregular concretions of ferric hydroxide that extend along the shores of lakes in which vegetation is abundant and into which streams carry iron-bearing water. The layers may attain a foot or two in thickness and are usually thickest at the water's edge and thin out toward the lake, few concretions being found where the water is more than 2 feet deep. The concretions themselves range from less than an inch to a foot or more in diameter. They contain quartz grains as impurities and are apparently formed around sand grains as nuclei by the rolling action of waves and currents. In the lower portion of such a layer of concretions, broken concretions with soft limonite and sand usually occur, and with them a green ferrous salt, perhaps a silicate or a sulphate, is generally found. Locally instead of concretions a layer of soft or hard, yellow, porous, bedded limonite occurs in the shallow water, and in still other places limonite occurs as cement in sand. In the deeper water of the lakes into which iron-bearing waters flow the distribution of the deposits is usually irregular, but in many places 6 to 8 feet of ocherous, slimy mud occurs at the bottoms of the lakes. Iron carbonate is usually absent in lake ore deposits.

The second type of bog ore usually forms in marshes, peat bogs, or other shallow surface depressions. These deposits may occur immediately at the surface but are more commonly found below several feet of porous surface soil and in many places are mixed with humus or peat. They form horizontal tabular bodies, as a rule of small circumference and of no great thickness. Some deposits have a pisolitic texture, consisting of small spherules of porous yellow ocher, the interstices of which are filled with hard brownish-black limonite; others consist of layers of concretions or nodules embedded in sand or sandy clay, and commonly contain much iron carbonate and vivianite; and still others form solid, thin, tabular bodies consisting of sand and clay impregnated and cemented by limonite. Where much peat is present irregular nests of bog ore that consist almost entirely of white, amorphous iron carbonate are numerous.[1] Such deposits are common in the Netherlands and northern Germany.

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[1] Van Bemmelen, J. M., Hoitsema, C., and Klobbie, E. A., Ueber das Vorkommen, die Zusammensetzung und Bildung von Eisenanhäufungen in und unter Mooren: Zeitschr. anorg. Chemie, Band 22, pp. 313–379, 1700.

[2] Moore, E. J., The occurrence and origin of some bog iron deposits in the district of Thunder Bay, Ontario: Econ. Geology, vol. 5, pp. 528–537, 1910.

Bog iron ores are distributed through many parts of the world but are especially abundant in the glaciated northern regions of North America, Europe, and Asia.[2] In these regions percolating waters dissolve iron from the glacial drift, where it is abundantly present as magnetite as well as iron silicates. Shaler states that in the glacial drift in New England 1 to 3 per cent of magnetite is found. The iron may be carried in solution as soluble carbonate, as sulphate, or combined with organic acids, and may be precipitated chemically or biologically. Chemical precipitation takes place either by removal of the solvents, by reaction with other materials in solution, or by oxidation. Biologic precipitation occurs through the action of microorganisms. Deposition usually takes place in small lakes or marshes, which are abundant in glaciated regions. The form in which the iron is precipitated depends on a number of factors, such as the form in which the iron is being carried in solution, the amount of oxygen present, the amount of organic matter present, and the presence of other materials in solution. Usually the conditions are so varied, however, that a mixture of iron salts is deposited, including ferric hydroxides, iron silicates, iron phosphate, and in places iron carbonate, iron sulphate, or iron sulphide, and perhaps ferrihumates or basic ferric salts. The deposition is described in more detail on pages 75–82.

Very few localities are known in which deposits of ferric hydroxide are at present forming in marine marshes, and it is supposed that the salts in solution in sea water interfere with the precipitation of ferric hydroxide. However, locally on the east coast of Brazil there are small areas of Tertiary marine sediments in which beds of sandy limonite are abundant, and in Huelva Bay, on the south coast of Spain, limonite is being deposited at present from iron-bearing mine waters. The "red mud," a terrigenous oceanic deposit which occurs locally on the borders of the continents in place of the more widespread "blue mud," also contains considerable ferric hydroxide.[3] Such deposits are forming along the coast of Brazil and in the Yellow Sea and are caused by abundant ocherous material being brought by the rivers to the ocean. Whether the precipitation of ferric hydroxide in these localities occurs in the waters of the rivers before they reach the sea or in the marine waters it is not possible to say.

DEPOSITS ORIGINALLY LAID DOWN MAINLY AS FERROUS CARBONATE.

Probably next in importance to ferric hydroxide as an original iron-bearing sediment is ferrous carbonate ($FeCO_3$). This compound has a theoretical composition of iron protoxide 62.1 per cent (Fe 48.2 per cent), and carbon dioxide 37.9 per cent.

Ores originally deposited mainly as iron carbonate include the clay ironstones and "black band" ores of the "Coal Measures" in both the United States and Europe, the oolitic siderite of the Jurassic in the Cleveland Hills and other parts of England, the cherty siderite and much of the hematite in the great pre-Cambrian iron-bearing beds of the Lake Superior district, and possibly a considerable part of the Jurassic oolitic limonite of northern France and southern Germany already described. Besides these ores there are large deposits of iron carbonate which have usually been regarded as originating by the replacement of limestone but many of which may be of primary origin. They include the beds of iron carbonate near Bilbao and in southern Spain, those of Erzberg in the Styrian Alps, and many others of minor importance.

Ironstone concretions and black-band ores of Carboniferous age occur in Ohio, Pennsylvania, West Virginia, and elsewhere in the eastern United States and also in Great Britain and parts of Germany. In the eastern United States ores of this nature are found principally in strata of lower Pennsylvanian age (Pottsville and Allegheny), though scattered beds occur both above and below this horizon. The siderite beds, which vary somewhat in form and structure, are classed under four groups. The most important of these groups are the limestone ores, so called because they occur at or near the top of limestone strata. These beds range from a few inches to several feet in thickness and have a pockety character because of variations in thickness in short distances. The ore is dense and close-grained and has a gray or bluish-gray color. The second type of siderite ore is called block ore because it cleaves into blocks when mined. These beds are more persistent and of more uniform thickness than the beds of limestone ore but usually contain a considerable amount of sand as impurity. The third group includes the concretionary or kidney ores. The ironstone concretions, though not regularly bedded, occur at definite stratigraphic horizons as peculiar rounded masses scattered through zones of clay or shale 3 to 6 feet thick. The fourth group, the black band ores, consist of iron carbonate with more or less intermixed bituminous and earthy matter. They occur as layers a few inches in thickness, interbedded with carbonaceous shale in zones 10 to 15 feet in thickness. They are generally of higher grade than the other carbonate ores. Where beds of iron carbonate of any of these types are exposed to weathering they are altered to limonite for varying distances from the outcrop.

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[1] Van Bemmelen, J. M., Hoitsema, C., and Klobbie, E. A., op. cit.

[2] Dake, C. L., The formation and distribution of bog iron ore deposits: Am. Inst. Min. Eng. Bull., July, 1915, pp. 1429–1436.

Shaler, N. S., General account of the fresh-water morasses of the United States: U. S. Geol. Survey Tenth Ann. Rept., pt. 1, p. 305, 1890.

[3] Murray, J., and Hjort, J., The depth of the ocean, pp. 161 et seq., 1912.

In Great Britain[1] three types of ironstone are mentioned, of which two are important—the black band ores, which are closely associated with coal seams, and the clay-band ores. Both types occur as beds or seams, lenslike in character and varying from a few inches to several feet in thickness. In central England there are a dozen or more important beds of black-band and clay-band ironstone in the Upper and Lower Coal Measures. The third type of iron carbonate ore is the nodular ironstone that occurs in parts of Ireland. The average range in composition of iron carbonate ores of the Coal Measures of Great Britain is, iron 26 to 35 per cent, silica 10 to 20 per cent, and phosphorus 0.5 to 1 per cent.

These sedimentary iron carbonate beds are supposed to have been formed by chemical precipitation from iron-bearing waters under conditions where oxidation could not take place. The presence of coal beds and carbonaceous shales in association with the ore indicates the presence of abundant vegetation at the time of deposition. The precipitation of iron carbonate probably occurs in shallow lagoons or marshes along the sea coast, and is due to the absorption by plants of the excess of carbon dioxide which held it in solution. Some of it may have been precipitated as ferric hydroxide, which upon settling to the bottom and becoming mixed with decaying organic material, was reduced to ferrous carbonate. Kidney ores were not originally deposited as such, but represent later segregations of iron carbonate originally deposited with muds.

Oolitic siderite beds of Middle and Lower Jurassic age[2] are found in the Cleveland Hills and in Northamptonshire, Lincolnshire, and elsewhere in the eastern part of England. The principal beds in the Cleveland Hills occur in the Middle Lias (Lower Jurassic), which consists of about 125 feet of nearly horizontal shale, sandstone, and ironstone. Four beds of ironstone occur, and these range in thickness from 1½ to 12 feet and have a combined average thickness of 16 feet. The main seam, which ranges in thickness from 6 to 12 feet, consists of impure bluish oolitic siderite that averages iron 30 to 35 per cent, silica 6 to 12 per cent, and phosphorus pentoxide (P_2O_5) 1 to 3 per cent.

In Northamptonshire there is only one important bed of iron carbonate, which lies at the base of the Lower Oolite (Middle Jurassic). Its maximum thickness is 30 feet and its average thickness throughout the district is about 9 feet. It is siliceous siderite of gray, green, or blue color and is oxidized to sandy brown or yellow limonite where exposed to weathering. The siderite averages in composition from 30 to 35 per cent of iron, 12 to 14 per cent of silica, and 0.5 to 1 per cent of phosphorus.

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[1] Louis, H., The iron resources of the United Kingdom of Great Britain and Ireland: The iron-ore resources of the world, Cong. géol. internat., Stockholm, p. 637, 1910.

[2] Louis, H., op. cit., p. 630.

The Lincolnshire ironstone bed occurs in the middle of the Lower Lias (Lower Jurassic). The thickness ranges from 10 to 25 feet, and averages about 12 feet. It lies nearly horizontal and where known consists mainly of calcareous brown hematite, having been oxidized by weathering agencies.

The oolitic siderites of England occur at approximately the same geologic horizons as the oolitic limonites of northern France and southern Germany, and this situation is somewhat suggestive of a similar origin. However, the Jurassic ores of England are mainly iron carbonate which is altered only at the surface to limonite, whereas the ores of France and Germany, where deep mining has taken place, do not seem to alter their character markedly with depth.

Probably the most extensive beds of iron carbonate known are those of the Lake Superior region already mentioned.[1] Though the iron-bearing formation as exposed at present in this region consists almost entirely of oxidized rocks, such as hematitic and limonitic chert and slate and iron ore, these rocks have been found to grade downward into cherty iron carbonate and silicate in a sufficient number of places to make the phenomenon appear fairly general.

The iron-bearing formation in the Lake Superior district is associated with basic volcanic rocks of Archean age and with metamorphosed sediments and volcanic rocks of lower, middle, and upper Huronian age. The beds are of great thickness and longitudinal extent, those of the upper Huronian being most widespread. Iron-bearing rocks of Archean and lower Huronian age are found only in the Vermilion district in northern Minnesota, and iron-bearing rocks of middle Huronian age are found only in the Marquette district in northern Michigan. The upper Huronian iron-bearing formation, however, is found throughout most of the Lake Superior district.

The Archean iron-bearing formation is infolded in Keewatin greenstone, the relation between them indicating that the iron-bearing formation is the younger. In places, however, bands of the iron-bearing formation are interbedded with greenstone flows, indicating contemporaneous origin. The lower Huronian iron-bearing formation lies on conglomerate and is overlain by slate. It is of little importance. The middle Huronian iron-bearing formation is underlain by slate and overlain unconformably by conglomerate and quartzite. The upper Huronian iron-bearing formation is in general underlain by quartzite or graywacke and is overlain by a great thickness of quartzose, micaceous, chloritic, and carbonaceous slate with associated basic volcanic rocks. Extensive layers and lenses of iron-bearing formation entirely inclosed in the slate also occur in the upper Huronian, as in the Cuyuna and Crystal Falls districts.

The unaltered beds of the iron-bearing formation consist largely of cherty siderite, grayish white to gray or greenish gray in color. With the cherty siderite are interbedded, here and there, layers of sideritic slate of grayish or greenish color. The cherty siderite in detail consists of interlaminated dense, fine-grained chert and siderite, usually in very thin layers. The average composition of cherty siderite is, iron 25 per cent and silica 40 per cent.

In their general occurrence and their relation to the inclosing sediments the Lake Superior cherty and slaty siderite beds resemble other sedimentary iron carbonates. Because of this general similarity they were formerly regarded as having the same origin. More recently, however, on account of their great thickness and their conspicuous association with basic volcanic rocks, a hypothesis has been advanced that ascribes their origin, at least in part, to igneous agencies.[2] The iron is supposed to have been derived from basic igneous rocks, the eruption of which occurred at approximately the same time as the formation of the iron-bearing sediments. These eruptive rocks, which are rich in iron, are now represented by greenstones, which occur at various horizons from the Archean to the upper Huronian. The iron, according to Van Hise and Leith, may have been derived from the eruptives in three ways: (1) A part may have been derived through processes of weathering from lavas extruded on land areas. (2) Another part may have been given off by reactions between sea water and hot subaqueous eruptive rocks. (3) Most of it, however, probably came from hot magmatic solutions that were squeezed out of the lavas during solidification.

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[1] Van Hise, C. R., and Leith, C. K., The geology of the Lake Superior region: U. S. Geol. Survey Mon. 52, 1911.

Irving, R. D., and Van Hise, C. R., The Penokee iron-bearing series of Michigan and Wisconsin: U. S. Geol. Survey Mon. 10, 1892.

Van Hise, C. R., Bayley, W. S., and Smyth, H. L., The Marquette iron-bearing district of Michigan: U. S. Geol. Survey Mon. 28, 1897.

Clements, J. M., Smyth, H. L., and Bayley, W. S., The Crystal Falls iron-bearing district of Michigan: U. S. Geol. Survey Mon. 36, 1899.

Clements, J. M., The Vermilion iron-bearing district of Minnesota: U. S. Geol. Survey Mon. 45, 1903.

Bayley, W. S., The Menominee iron-bearing district of Michigan: U. S. Geol. Survey Mon. 46, 1904.

Harder, E. C., and Johnston, A. W., Preliminary report on the geology of east-central Minnesota including the Cuyuna iron-ore district: Minnesota Geol. Survey Bull. 15, 1918.

[2] Van Hise, C. R., and Leith, C. K., op. cit., pp. 499 et seq.

The precipitation of the iron carbonate and silicate from solution is believed to have been the result of simple chemical reactions between ferrous solutions, alkaline silicates, and carbon dioxide. The deposition of the iron-bearing sediments took place in marine waters, the ferruginous materials being distributed over large areas by currents. The conditions of deposition differed considerably in different parts of the district and in the different epochs, causing a great diversity in the occurrence of the iron-bearing sediments.

The iron carbonate deposits of Bilbao, in northern Spain, are scattered over an area about 30 kilometers in length and 2 to 8 kilometers in width.[1] They occur as irregular tabular masses in the upper part of a thick Cretaceous limestone overlain by calcareous shale. The masses are said to have a maximum thickness of 100 feet. Along the outcrop and for some distance in from the surface they are altered to hematite and limonite.

The iron carbonate is supposed to have been formed by the replacement of limestone by iron-bearing waters that percolated downward from the overlying shale. Their tabular shape and their occurrence at a definite horizon, however, suggest the possibility of their direct sedimentary origin.

The iron carbonate ore in northern Styria occurs in the so-called "graywacke zone," a complex of Paleozoic rocks lying between the granite, schist, and gneiss of the central part of the eastern Alps and the Triassic sediments of the northern part.[2] It is found over an area about 50 kilometers in length, east and west, as scattered deposits.[3] The principal ore bed occurs at Erzberg and has a maximum thickness of 125 meters. Underlying it unconformably is the Sauberg limestone of Lower Devonian age, which consists of interlayered limestone and ankerite. The ankerite commonly passes over into siderite. Between the main ore bed and the limestone is a thin bed of dark sericitic schist. Overlying the ore bed unconformably are Lower Triassic rocks, which consist of first a conglomerate and then a grayish-green sandstone, which passes upward into red Werfener slates. The ore bed itself consists of dense fine-grained siderite and here and there contains more coarsely crystalline siderite along fissures and fractures. Local interbedded layers of shale and limestone are found in it.

The generally accepted hypothesis for the origin of this ore is that it was formed by the metasomatic replacement of limestone by iron brought in by percolating waters. The chief evidence cited is that small siderite deposits are irregularly distributed in the Sauberg limestone and that sulphides occur in the ore beds. However, the well-developed bedding of the iron carbonate and the fact that fragments of ore occur in the basal Triassic conglomerate above the ore bed would indicate that at least the principal ore bed is of sedimentary origin,[2] though the siderite in the Sauberg limestone may be a later replacement.

DEPOSITS ORIGINALLY LAID DOWN MAINLY AS IRON SILICATES.

Iron silicates of several kinds occur as sediments, the most widespread probably being glauconite. This mineral has no definite chemical composition but is essentially a hydrous silicate of iron and potassium with some alumina. When pure it probably has approximately the composition represented by the formula $Fe'''KSi_2O_6.aq.$[1] Alumina may replace a part of the iron. The iron is largely in the ferric form, but a variable though small amount of ferrous iron is always present. Glauconite is common in sedimentary rocks of many different ages but especially of the Cretaceous. It is usually more or less disseminated, but locally it forms pure beds and lenses.

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[1] Vidal, L. M., Résumé des gisements de fer de l'Espagne: The iron ore resources of the world, Con. géol. internat., Stockholm, p. 49, 1910.

Adams, F. D., Notes on the iron-ore deposits of Bilbao, northern Spain: Canadian Min. Inst. Jour., vol. 4, pp. 196–204, 1901.

Czyszkowski, M. S., Exploration géologique de la région ferrifère de Bilbao-Somorrostro, 1879.

John, Die Eisenerzlagerstätten von Bilbao und ihrer Bedeutung für die zukünftige Eisenversorgung Grossbritanniens und Deutschlands: Glückauf, vol. 46, pp. 2002–2013, 2045–2052, 1910.

[2] Singewald, J. T., jr., The Erzberg in Styria: Eng. and Min. Jour., vol. 92, p. 22, 1911.

[3] Uhlig, V., Die Eisenerzvorräte Oesterreichs: The iron-ore resources of the world, Cong. géol. internat., Stockholm, p. 143, 1910.

Another important iron silicate found in sediments is the hydrous ferrous or ferrosoferric silicate, greenalite, which occurs along with cherty siderite as an original constituent locally in the Lake Superior iron-bearing formation.[2] Greenalite has the composition $FeSiO_3.nH_2O$ or $Fe'''_2Fe''_3(SiO_4)_3.3H_2O$. A part of the ferrous iron may be replaced by magnesium.

Besides these there are four other more or less related hydrous silicates of iron—thuringite, chamosite, berthierine, and bavalite—which are quite widespread. Only the first of these has a definite chemical formula, which is as follows: $8FeO.4(AlFe)_2O_3.6SiO_2.9H_2O$ (silica, 22.8 per cent; alumina, 17.2 per cent; ferric oxide, 13.5 per cent; ferrous oxide, 36.3 per cent; combined water, 10.2 per cent). The other three silicates differ from thuringite in that they contain a higher percentage of iron protoxide, only a small percentage of alumina, and little or no ferric iron.

Thuringite and chamosite are said to be the principal minerals in certain lenses of iron ore of Lower Silurian age in Bohemia and in Thuringia, Germany. Thuringite is olive-green in color and scaly, and chamosite is dark grayish green and either compact or oolitic. Chamosite is an abundant constituent of the Wabana iron ore of Newfoundland, in which it is associated with compact and oolitic hematite. Berthierine occurs in northern France as a constituent of the Jurassic oolitic ores, associated with limonite, siderite, and other minerals.[3] Bavalite is found in scattered deposits in Brittany, where it is interbedded with metamorphosed rocks.[4]

Glauconite occurs as dark-green granules widely distributed in sedimentary rocks and is also being deposited at the present time in many places on the ocean bottom. It forms a green granular sediment and is generally more or less mixed with other sedimentary material, especially fine sand and silt. The separate granules usually have the shape and size of foraminiferal shells, and many of them still have fragments of shells attached to the outside of them. Many also are distinct internal casts of Foraminifera. Very few glauconite grains exceed 1 millimeter in diameter.

At the present time glauconite is forming most abundantly in comparatively shallow waters and near the mud line surrounding the continental shores just beyond the limit of wave and current action.[5] The depth at which it commonly forms ranges between 100 and 200 fathoms, but in some places it forms at depths as great as 900 fathoms. The entrance of large rivers interferes with its formation.

The common occurrence of glauconite inside shells of Foraminifera has led to the belief that these organisms are concerned in its formation. The dead organisms are supposed to drop to the bottom, whereupon the shells become filled with fine mud which in the presence of the sulphates in sea water is acted upon by the decaying organic matter in the shell.[6] The iron supposed to be contained in the mud is reduced to sulphide, and this afterward oxidizes to ferric hydroxide, setting free sulphuric acid. The sulphuric acid acts upon the alumina, causing it to be removed in solution and at the same time colloidal silica is set free. The colloidal silica reacts upon the ferric hydroxide and in the presence of potassium salts, supposed to be derived from adjacent decomposing minerals, forms glauconite. Sediments with which glauconite is associated are said to contain invariably abundant orthoclase, muscovite, and other minerals from which potassium may have been derived. Other materials commonly found with glauconite in greensand are quartz, hornblende, magnetite, augite, zircon, garnet, and varying amounts of calcareous matter derived from shells.

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[1] Clarke, F. W., The data of geochemistry, 3d ed.: U. S. Geol. Survey Bull. 616, p. 517, 1916.

[2] Leith, C. K., The Mesabi iron-bearing district of Minnesota: U. S. Geol. Survey Mon. 43, pp. 239 et seq., 1903.

Van Hise, C. R., and Leith, C. K., The geology of the Lake Superior region: U. S. Geol. Survey Mon. 52, pp. 165, 521, 1911.

[3] Clarke, F. W., The data of geochemistry, 3d ed.: U. S. Geol. Survey Bull. 616, pp. 516–518, 1916.

[4] Dana, E. S., System of mineralogy, p. 658, 1914.

[5] Murray, J., and Renard, A. F., *Challenger* Rept., Deep-sea deposits, p. 383, 1891.

[6] Clarke, F. W., The data of geochemistry, 3d ed.: U. S. Geol. Survey Bull. 616, p. 135, 1916.

Murray, J., and Renard, A. F., op. cit.

Glauconite is disseminated in marine sediments of all geologic ages, forming strata which are known as greensand. In the Paleozoic rocks greensand is probably most abundant in Cambrian and Ordovician strata. Cambrian greensand is common in the north-central United States, where it is associated with siliceous limestone and fine calcareous sandstone beds. Ordovician ("Lower Silurian") greensand occurs in the Baltic provinces of Russia. In the Mesozoic rocks glauconite is particularly abundant in the Cretaceous formations both in Europe and North America. In England it occurs throughout the southern counties as well-defined beds generally interlayered with sand, marl, and clay. It is so abundant along certain zones that they are known as greensand horizons. The principal greensand horizons are in the upper part of the Lower Cretaceous and in the lower part of the Upper Cretaceous. The principal chalk beds occur above them in the Upper Cretaceous. In the Atlantic and Gulf coastal sediments of the United States greensand occurs in the Cretaceous and in the overlying Eocene deposits.[1] It is found more or less abundantly throughout the strata, being associated with coarse and fine sand, clay, and marl. Locally beds of pure glauconite occur.

Below is shown the range in composition of glauconite obtained from different localities.[2]

Range in composition of glauconite from different localities.

SiO_2	40. 00–53. 61
Al_2O_3	6. 62–13. 00
Fe_2O_3	15. 16–23. 43
FeO	1. 32–10. 17
MgO	.95– 2. 97
CaO	.57– 1. 97
Na_2O	.42– 2. 16
K_2O	3. 49– 9. 54
H_2O	4. 93–10. 32

The occurrence and character of the Lake Superior iron-bearing formation have already been described. Although cherty siderite is the principal rock in the unaltered iron-bearing formation, there are localities in the Penokee-Gogebic district where a considerable amount of greenalite occurs with it, along certain horizons, and other localities, as in the Mesabi district, where most of the formation is believed to have originally consisted of greenalite.[3]

Greenalite forms a dark-green, hard, compact rock with oolitic texture. The greenalite spherules have a maximum diameter of a millimeter or more and in shape they vary from spherical to oval or elliptical. They differ from spherules of Clinton hematite and Wabana ore in that they do not show concentric layering. They are usually homogeneous throughout and consist of green amorphous material which in places has a little siderite or chert or crystalline ferrous silicate intermixed. The matrix in which the spherules are embedded consists in places of chert and elsewhere of a light-greenish crystalline ferrous silicate, probably grünerite.

Greenalite rock may occur as beds of considerable thickness, but as a general rule it is thin bedded and is interlayered with thin beds of dense black ferruginous slate. Upon exposure to surface weathering the greenalite rock is altered to a peculiar granular, speckled, hematitic chert to which the name taconite has been given.

The following shows the range in composition of greenalite from the Mesabi district, Minn.[4]

Range in composition of greenalite from Mesabi district, Minn.

SiO_2	46. 12–61. 90
Al_2O_3	.37– 1. 09
Fe_2O_3	5. 01–15. 00
FeO	10. 28–30. 93
MgO	2. 33– 5. 35
CaO	.00– .28
H_2O-	.75– 2. 50
H_2O+	4. 17– 6. 41

The chamosite ores of Bohemia are found in the Brdagebirge, the principal deposits occurring in the region of Nučitz.[1] Beds of this ore are located at the base and near the top of a certain horizon in the Silurian known as horizon "D."

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[1] Clark, W. B., Origin and classification of the greensands of New Jersey: Jour. Geology, vol. 2, pp. 161–177, 1894.

[2] Clarke, F. W., op. cit., p. 518.

[3] Leith, C. K., The Mesabi iron-bearing district of Minnesota: U. S. Geol. Survey Mon. 43, pp. 101 et seq., 1903.

[4] Idem, p. 108.

The base of horizon "D" consists of graywacke and slate with sheets of diabase and diabase tuff and layers of iron ore which seem to be genetically related to the diabase. The iron ore is mainly oolitic hematite, but oolitic ferrous silicate (mainly chamosite) is abundantly associated with it. It occurs in lenticular beds which range from a thin film to 18 meters in thickness and is widely distributed. Near the surface the chamosite is altered to limonite.

In the upper part of horizon "D" also several zones containing beds of iron ore occur. The rocks consist mainly of graywacke and graywacke slate, the former containing light-colored quartzite layers. The ore beds are associated with the slates. They are lenticular in shape and in places, as in the vicinity of Nučitz, reach a maximum thickness of 22 meters. The ore is oolitic dark-green or bluish-green ferrous silicate with a more or less sideritic or slaty matrix. At the surface it is altered to limonite. The beds are lens-shaped and pinch out horizontally.

Near Schmiedefeld, in the Thuringian Forest, widely distributed beds of ferrous silicate occur in rocks of Lower Silurian age. They extend over many square miles and are so constant that they are taken as horizon markers. The lower bed, which is unimportant, is found just above a Cambrian quartzite and grayish-green argillaceous schist and is overlain by a few meters of micaceous quartzite schist. This is overlain by the main ore bed, 15 to 20 meters thick, above which are Lower Silurian clay slates.[2] The lower bed is only a few meters thick and locally is represented by two layers. It contains much hematite, usually oolitic. The upper bed is extensive and consists of chamosite and thuringite, the former being predominant. The chamosite is silver-gray to black in color and shows oolitic texture. At the surface it alters to limonite. The thuringite is olive to dark green in color and fine scaly, dense, or oolitic in texture. A large quantity of iron carbonate occurs with the ferrous silicates.

The association of chamosite with hematite in the Newfoundland oolitic iron-ore beds has been mentioned on page 50.[3] It is found in the spherules and in the interstices between the spherules composing the ore beds and occurs also in the matrix of the clastic sediments that inclose the ore beds. In the leaner portions of the ore layers chamosite is abundant in the spherules and either occurs concentrically interlayered with hematite or forms entire spherules itself. In this form it is usually dense and amorphous. In the matrix between the spherules and in the inclosing clastic rocks the chamosite is nonoolitic and shows a microcrystalline or finely crystalline texture. Occasionally it forms large tabular crystals.

Hayes[4] gives the following recalculated average analyses of Wabana chamosite:

Recalculated average analyses of Wabana chamosite from Newfoundland.

SiO_2	24.87	23.23	25.64
Al_2O_3	19.45	22.85	19.75
Fe_2O_3	6.66	1.00	......
FeO	34.52	38.99	39.74
MgO	3.34	3.25	2.98
H_2O	11.16	10.68	11.89

The color of chamosite varies from light to deep green and occasionally has a grayish tint. Tubes, supposed to be those of boring algae, are abundant in the ore beds. Where these tubes penetrate chamosite they are usually lined with a coating of hematite, which is believed to have resulted from the oxidation of the chamosite by the action of the algae.

DEPOSITS ORIGINALLY LAID DOWN MAINLY AS IRON SULPHIDE.

Iron disulphide (FeS_2; iron, 46.6 per cent; sulphur, 53.4 per cent) is abundant in sedimentary rocks, occurring both as disseminated specks and nodules and as beds and lenses. It is generally present as pyrite, but in some recent sediments the black iron disulphide, melnikowite, has been found also. Marcasite more commonly occurs as a vein mineral. Ferrous sulphide (FeS) forms a constituent in some modern lacustrine and marine sediments.

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[1] Beyschlag, F., Krusch, P., and Vogt, J. H. L., Die Lagerstätten der nutzbaren Mineralien und Gesteine, Band 2, pp. 528 et seq., 1913.

Uhlig, V., Die Eisenerzvorräte Oesterreichs: The iron-ore resources of the world, Cong. géol. internat., Stockholm, pp. 148 et seq., 1910.

[2] Beyschlag, F., Krusch, P., and Vogt, J. H. L., op. cit., Band 2, pp. 531 et seq.

[3] Hayes, A. O., op. cit., p. 26.

[4] Idem, p. 62.

Lenses of crystalline pyrite, of probable sedimentary origin but more or less recrystallized, occur interbedded with metamorphic rocks such as slate, schist, and quartzite, in Spain, France, Italy, Austria, Norway, and many other parts of the world. Beds of oolitic pyrite occur in the Ordovician rocks of Newfoundland, and in the Devonian rocks of Westphalia, Germany. Melnikowite has recently been described as occurring in Miocene clays in southeastern Russia.

More interesting probably than these, however, are the deposits of hydrous ferrous sulphide which characterize the black mud forming at present in the bottom of the Black Sea and neighboring limans and in bays on the island of Oesel, Gulf of Riga, and elsewhere. Iron sulphide, some of which is probably in the ferrous form, also characterizes the "blue mud" deposited locally in the ocean bottom.

In the Huelva region in southern Spain[1] lenses of pyrite occur in sedimentary rocks, mainly clay slate with some graywacke and limestone belonging to the Culm (Lower Carboniferous). The rocks are highly folded and faulted and have steep dips. The lenses have a maximum length of more than 1,100 meters and a maximum width of 180 meters. They occur at different horizons in the Culm and most of them are said to be closely associated with intrusive sheets of porphyry. On account of this association the pyrite lenses are usually described as being epigenetic in origin and as having been formed by hot solutions from the porphyry magma. Their interlayering with the sediments, however, and close concordance with them in strike and dip make a sedimentary origin not impossible. The Huelva pyrite lenses are important copper bearers and contain also some lead, zinc, arsenic, and silver, the occurrence of which is taken as additional evidence for their epigenetic origin.

At Agordo, in the Venetian Alps of northern Italy,[2] lenses of pyrite, similar to those in the Huelva region, occur interlayered with pre-Carboniferous metamorphosed argillaceous schist, usually not far from masses of intrusive quartz porphyry. The lenses have a maximum length of 550 meters and a maximum width of 200 meters and show fine-grained texture and distinct layering. In metal content they resemble the Huelva pyrite lenses. Their origin must be explained along similar lines.

In the Carpathians at Szomolnok[3] pyrite lenses occur in folded and metamorphosed sediments of the Culm, consisting of graphitic and chloritic schist and quartzitic sandstone. Intrusive diorite and porphyry occur in the schist. The pyrite lenses are found in distinct layers corresponding in structure with the metamorphosed sediments. However, they are usually explained as being of epigenetic origin, resulting from the diorite intrusions.

At Rammelsberg, near Goslar,[4] on the northwestern border of the Harz Mountains in central Germany, a lens of pyrite occurs interlayered between two slate beds of Middle Devonian age, which stratigraphically overlie Lower Devonian coarse sandstone. The beds are folded into an overturned anticline of which the sandstone forms the center. The pyrite lens occurs on the lower limb of the anticline and has been folded with the inclosing slates, following the contortions of the slates closely. It generally ranges in thickness from 0.5 meter to 3 meters, and shows marked banding parallel to the lens, which in part is due to included thin layers of slate. The principal minerals are pyrite, zinc blende, chalcopyrite, galena, and arsenopyrite in a gangue of barite.

It is generally believed that the Rammelsberg pyrite deposit is a contact vein formed by magmatic solutions. Recently, however, fossils of *Goniatites* have been found in the pyrite bed, which has led to its reclassification by some authors as a sedimentary deposit.[5]

The oolitic pyrite bed in Westphalia occurs at Meggen on the Lenne.[6] By some authors it is considered as of sedimentary origin and by others as a later introduction. The bed consists of pyrite and barite and averages about 10 feet in thickness. The pyrite occurs in fine layers, distinctly stratified and in places oolitic. Underlying it are graywacke slates and overlying it is a bed of dense nodular limestone, in part dolomitic, carrying inclusions of iron pyrite. Above the limestone are clay slates. The rocks are of Devonian age.

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[1] Beyschlag, F., Krusch, P., and Vogt, J. H. L., Die Lagerstätten der nutzbaren Mineralien und Gesteine, Band 1, pp. 311–323, 1910.

[2] Idem, pp. 326–328.

[3] Idem, pp. 329–331.

[4] Lindgren, Waldemar, Mineral deposits, pp. 606–610, 1913.

[5] Beyschlag, F., Krusch, P., and Vogt, J. H. L., op. cit., Band 2, pp. 630–637, 1913.

[6] Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, Band 1, pp. 339–342, 1904.

The oolitic pyrite beds which are associated with the Wabana hematite beds of Newfoundland are probably the most typical sedimentary pyrite beds known.[1] The pyrite-bearing zone is found just above one of the principal hematite beds (the Dominion bed), being separated from it by 1 to 10 feet of shale or sandstone. There are one to three beds of pyrite ranging in thickness from an inch to a foot or more and separated by fissile black shale. The beds thicken, thin, and die out within short distances, but the zone is persistent. Shale occurs above the pyrite beds. The pyrite nearly all has a distinct oolitic texture and together with the inclosing shale contains abundant graptolites and some brachiopods, showing its marine origin. Associated with the pyrite spherules are nodules and small irregular bodies of pyrite. Quartz occurs both as fragments and as a matrix between pyrite spherules.

In the southeastern part of Russia near Nowo-Usensk in the Government of Samara, clays containing iron sulphide were encountered in drilling natural gas wells.[2] The succession of strata passed through in these borings is as follows:

Section penetrated in borings near Nowo-Usensk, Samara, Russia.

	Feet.
Post-Tertiary:	
Brown clay	150
Clayey sand containing magnesium sulphate bearing water	35
Sandy clay	5
Miocene:	
Brown clay, in part sandy, with layers of gas-bearing sand	115

The Miocene brown clay is interesting in that it carries a black iron sulphide, melnikowite, which occurs finely disseminated through the clay, as well as in streaks and thin layers. Particles of it are commonly attached to fragments of fossil mollusks. As obtained from the bore holes the melnikowite was mainly in the form of dull, dense, compact fragments, generally with concentric structure. Associated with these fragments were found spherical, oval, grapelike, or kidney-shaped forms, the largest of which were 1 millimeter in diameter. The microscopic texture of the melnikowite is finely crystalline and the color black. Analysis has shown it to be iron disulphide (FeS_2), but it differs from marcasite and pyrite in being strongly magnetic and in various other physical properties.

The particles of melnikowite are somewhat impure, containing quartz and calcite grains, clay particles, or fine muscovite flakes. Much of the melnikowite also has associated with it particles and grains of finely crystalline pyrite, whose occurrence and gradation into melnikowite suggest strongly that the pyrite is a stable form into which the melnikowite is altering.

Black muds containing abundant organic material and impregnated with colloidal hydrous ferrous sulphide occur in many localities both in inclosed seas and in gulfs and bays connected with the open ocean.[3] Among the best-known localities are the eastern Mediterranean Sea, Black Sea, Sea of Azov, Caspian Sea, Dead Sea, Aral Sea, and other inclosed bodies of water in southeastern Europe and western Asia. Similar muds, however, also occur around Oesel Island and elsewhere in the Gulf of Riga, at several localities in the southern Baltic Sea, around the mouths of the Elbe and the Weser, and along the Netherlands coast in the North Sea, as well as locally on the coast of Scotland. Many sulphur springs throughout Europe contain black muds that carry ferrous sulphide, and the "blue mud" of the ocean bottom along the edges of the continents is also characterized by iron sulphide, part of which is doubtless in the ferrous form.

The "blue mud" of the ocean bottom is blue or slate-colored, but the upper layer in contact with the water is oxidized to red or brown. The blue color is due to the presence of organic matter and sulphide of iron in a fine state of division. It has the smell of sulphureted hydrogen. The depth at which it occurs ranges from 125 to 2,800 fathoms. "Blue mud" contains, besides terrigenous clastic material, abundant remains of Foraminifera, Radiolaria, diatoms, sponge spicules, and fragments of mollusk and echinoderm shells.

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[1] Hayes, A. O., Wabana iron ore of Newfoundland: Canada Geol. Survey Mem. 78, p. 15, 1915.

[2] Doss, Bruno, Ueber die Natur und Zusammensetzung des in Miocaenen Tonen des Gouvernements Samara auftretenden Schwefeleisens: Neues Jahrb., Beilage Band 33, pp. 662–713, 1912; Melnikowit, ein neues Eisenbisulphid und seine Bedeutung für die Genesis der Kieslagerstätten: Zeitschr. prakt. Geologie, Jahrg. 20, pp. 453–483, 1912.

[3] Doss, Bruno, Neues Jahrb., Beilage Band 33, pp. 689 et seq., 1912. (Numerous references cited.)

The "blue muds" surround nearly all the continents and occur in inclosed seas like the Mediterranean, and even in the Arctic Ocean. They occupy the largest area of the terrigenous oceanic deposits.[1]

The following table shows the range in composition of the principal constituents of blue mud:

Range in composition of the principal constituents of blue mud.

SiO_2	59.54–64.20
Al_2O_3	13.55–19.42
Fe_2O_3	7.15–11.23
Loss on ignition[2]	4.92– 6.24

Small amounts of soda, potash, lime, and magnesia are also present.

Recent studies of muds from the bottom of the Black Sea and neighboring limans[3] as well as from other inclosed seas of southeastern Russia, have shown that they contain an abundance of ferrous sulphide. As indicated by the dredgings two kinds of mud exist in the Black Sea at depths of 300 to 717 fathoms. One type is a sticky black mud containing hydrous ferrous sulphide ($FeS.nH_2O$) presumably as a gel. The other type is a less dense blue mud containing pelagic diatoms, a smaller quantity of ferrous sulphide, and concretions of iron disulphide. The blue mud is believed to underlie the black mud, and its existence proves that iron disulphide undoubtedly occurs at least locally in unconsolidated ferrous sulphide bearing muds.

In some of the limans and shallow lakes of southern Russia ferrous sulphide generally occurs as an intermixed paste or as lumps and concretions in black mud, or as coatings of other substances, but it is also found with moist black shore muds and sands.

The limans bordering the Black Sea are shallow, salty lagoons separated from the open water by low, narrow bars.[4] The bottoms of these lagoons are covered with a tough, black mud which owes its color to an abundance of ferrous sulphide. The mud is plastic and doughy, has a strong odor of hydrogen sulphide, and gives an alkaline reaction. It consists of clay particles, fine sand, and shells, which are impregnated with and held together by colloidal, hydrated ferrous sulphide and abundantly mixed with decomposing organic material derived from both plants and animals. The liman mud is used for healing purposes on account of its content of hydrogen sulphide, but when exposed to the air the ferrous sulphide oxidizes and the mud takes on a gray color. However, upon being reimmersed in brine it is again reduced, owing to the action of reducing bacteria, which are present abundantly.

Doss's explanation[5] of the origin of sedimentary deposits of iron sulphide is as follows: Iron is dissolved from iron-bearing minerals and carried in solution as soluble ferrous carbonate ($Fe(CO_3)_2$) by surface waters to inclosed bays or lagoons in which decaying organic matter is abundant. Here the iron is precipitated, either directly as black colloidal hydrated ferrous sulphide by reaction with hydrogen sulphide liberated by bacteria from the decaying organic matter, or as ferric hydroxide by iron bacteria. Ferric hydroxide under reducing conditions and in the presence of hydrogen sulphide is changed to hydrated ferrous sulphide. By loss of water and the addition of sulphur, which occurs as free sulphur in the mud, the hydrated ferrous sulphide is changed to melnikowite (FeS_2). The melnikowite alters gradually to pyrite and the inclosing mud becomes hardened and cemented to clay and shale. Where iron sulphide was originally mixed with the mud it was later disseminated through the resulting rocks, but where more or less pure deposits occurred they resulted in the formation of beds and lenses of pyrite. Later metamorphism may cause the recrystallization of the pyrite lenses and alteration of the inclosing rocks to slate and schist. Thus all stages occur between the black ferrous sulphide muds forming in many inclosed basins and the recrystallized lenses of pyrite interbedded with slates and schists.

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[1] Murray, J., and Renard, A. F., *Challenger* Rept., Deep-sea deposits, pp. 229 et seq., 1891.
Murray, J., and Hjort, J., The depth of the ocean, pp. 161 et seq., 1912.

[2] Organic matter, sulphur, etc.

[3] Andrussow, N., La mer noire: Cong. géol. internat., Guide des exc., 7° sess., Excursion 29, p. 7, 1897, cited by Hayes, A. O., op. cit., p. 90.

[4] Omelianski, W., Der Kreislauf des Schwefels, in F. Lafar's Handbuch der technischen Mycologie, Band 3, pp. 222–223, 1904–1906.

[5] Doss, Bruno, Zeitschr. prakt. Geologie, Jahrg. 20, pp. 460–461, 1912.

Many of the pyrite lenses in schists and other metamorphic rock, such as the deposits at Huelva and those of Agordo and Szomolnok, have been fairly definitely shown to be related, at least in part, to igneous intrusions. The igneous rocks may have caused the formation of the entire deposits or they may simply have caused the recrystallization of original lenses of iron sulphide and the introduction into them of their content of silver, lead, zinc, copper, and other metals. It must be remembered that deposits of iron sulphide are forming abundantly at the present time in association with argillaceous sediments, which upon metamorphism would yield just such rocks as those in which we find the lenses of pyrite containing copper, lead, and zinc sulphides. The facts that these lenses are distinctly conformable to the bedding of the rocks in which they occur, that many of them exhibit banding parallel to the bedding of the associated rocks, and also that many are far removed from igneous intrusions, are strong points in favor of their original sedimentary origin. The reason why only a few deposits of iron sulphide that are clearly of sedimentary origin, such as those of Russia and Newfoundland, have been described in the literature can perhaps be sought in their relative unimportance commercially, which is due to their lack of precious or semiprecious metals.

FORMATION OF SEDIMENTARY IRON-BEARING DEPOSITS.

DEPOSITION OF IRON BY MECHANICAL PROCESSES.

There are certain iron-ore deposits which have been formed almost entirely by mechanical processes. To this type belong the black sands, which consist of magnetite or hematite sand mixed with particles of other hard, heavy minerals, such as garnet, zircon, ilmenite, rutile, quartz, and chromite.

The processes which are most active in the formation of black sands are disintegration and transportation. The rocks that contain disseminated iron minerals upon being subjected to disintegration without much decomposition release the separate mineral particles, which are then carried away by streams and finally sorted by currents and waves according to their density. Black sands may form on the seashore or on the shores of rivers or lakes. Their specific gravity prevents the particles from being carried very far from shore, though moderately swift flowing streams may carry them some distance, along with other coarse clastic material, and deposit them in their deltas.

In general black sand deposits are very impure on account of the admixture of non iron-bearing clastic particles. In many places also they are very high in titanium owing to the presence of abundant ilmenite. Deposits of magnetite sands are forming at the present time along the sea coast and along the larger rivers in Washington, Oregon, and California. Deposits of hematite sand are forming along streams in Minas Geraes, Brazil, the materials being derived from the disintegration of the extensive beds of hematite-bearing quartzite that occur in that region. Though most of the known black sand deposits are of recent origin, older beds of a similar character are met with locally, such as the black sand beds in Upper Cretaceous rocks in northwestern Montana.[1]

Other iron-ore deposits that are formed largely by mechanical processes are the detrital talus deposits, consisting of blocks and fragments of ore, which commonly lie on slopes below outcropping cliffs of iron ore. They are generally designated by the name of rubble ore. Such deposits may become cemented by the filling of the spaces between the fragments and thus result in clastic breccias. To this type belong the "canga" ores of Brazil, which are drived from and associated with the bedded hematite. Some fragmental varieties of laterite which occur in India in association with the Dhárwar iron-bearing sediments may also be classed with this type.

DEPOSITION OF IRON BY CHEMICAL PROCESSES.

FORMATION OF DEPOSITS OF FERRIC HYDROXIDE.

Ferric hydroxides may be precipitated either from organic or inorganic iron solutions, the reaction being accompanied by hydrolysis in ferric compounds and by oxidation with hydrolysis in ferrous compounds. The ferric hydroxides form a gradational series in which iron, in the form of Fe_2O_3, is associated with water. This water (meaning "water above 105° C.") ranges from a few per cent, as in hydrated hematite, to an unknown upper limit, perhaps more than 30 per cent. These amounts of "water" probably range through all the possible varieties of combinations, as with most other hydrated oxides, from hydroxyl groups to firmly held hygroscopic moisture. In general the series of ferric hydroxides is probably analogous to the various hydrated forms of silica. A large number of ferric hydroxides have been prepared or are found in nature as minerals, but the exact composition of many of these is uncertain.[1]

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[1] Stebinger, Eugene, Titaniferous magnetite beds on the Blackfeet Indian Reservation, Mont.: U. S. Geol. Survey Bull. 540, pp. 329-337, 1914.

Much work was done on the constitution of ferric hydroxides during the nineteenth century, of which the most important was that of Muck,[2] Tomassi,[3] van Bemmelen,[4] and Ruff.[5] Muck first and Tommasi later, by chemical precipitation from iron solutions, obtained two different classes of ferric hydroxides, the red hydroxides and the yellow hydroxides. The red hydroxides are obtained by precipitation from ferric salts with alkalies, whereas the yellow hydroxides are obtained by the oxidation of moist ferrous hydroxide or of ferrous carbonate. By drying freshly prepared precipitates of ferric hydroxide at different temperatures Tommasi obtained the following compounds, which he regarded as definite hydroxides:

Yellow hydroxides:
    $Fe_2(OH)_6$--------Forms below 70° C.
    $Fe_2(OH)_4O$------Forms between 70° and 105° C.
    $Fe_2(OH)_2O$------Forms between 105° and 150° C.
Red hydroxides:
    $Fe_2(OH)_6$--------Not obtained.
    $Fe_2(OH)_4O$------Forms below 50° C.
    $Fe_2(OH)_2O_2$------Forms between 50° and 92° C.

Upon further heating of the red hydroxides a brown anhydrous ferric oxide having a specific gravity of 5.1 was produced, but the anhydrous ferric oxide resulting from heating the yellow hydroxides was reddish yellow in color and had a specific gravity of 3.95. Tommasi concluded from these data that there exist two distinct series of ferric hydroxides with different properties.

Van Bemmelen in his experiments with colloids showed that red ferric hydroxides are really colloidal substances without any definite chemical composition, the amount of water retained by them being dependent on the aqueous vapor pressure in the atmosphere, with which they are in equilibrium. Only at high temperatures are they converted to anhydrous ferric oxide. He believed that the red hydroxides do not differ in any essential way from the yellow hydroxides and that the latter also are colloids in perhaps a little more stable and concentrated form.

If these conclusions are correct it is difficult to understand under what conditions various stable ferric hydroxides found in nature are formed, and further how deposits of anhydrous or slightly hydrated ferric oxide are formed so abundantly under natural conditions when in the laboratory high temperatures are necessary for their formation.

Realizing the discrepancies between the conclusions of Tommasi and Van Bemmelen, Ruff took up the study of the ferric hydroxides. His first experiments were performed with red colloidal ferric hydroxide under ordinary conditions of pressure but with varying temperature. They confirmed more or less the work of Van Bemmelen. He found also that the freshly precipitated red ferric hydroxide, when allowed to stand for several years at ordinary temperatures, gradually lost water but before becoming entirely anhydrous began to take on water again and after 10 or 15 years changed to the normal stable ferric hydroxide, $2Fe_2O_3.3H_2O$.

The second series of experiments of Ruff was performed with ferric hydroxide under varying pressures of about 5,000 atmospheres. By raising the temperature under these conditions of pressure he found that the colloidal red ferric hydroxides became converted into definite hydroxides all found in nature, the particular hydroxide formed depending on the temperatures. Between 30° and 42.5° C. the colloid changed to a yellow granular powder having the water content and specific gravity of limonite ($2Fe_2O_3.3H_2O$), between 42.5° and 62.5° C. it became yellowish red and took on the properties of goethite ($Fe_2O_3.H_2O$), and above 62.5° C. it became brick-red and had the composition of turgite ($2Fe_2O_3.H_2O$). Ruff did not obtain the anhydrous oxide, hematite, at high pressures below a temperature of 150° C. The yellow hydroxide, when treated under similar conditions with a range of temperature from 40° to 70° C., behaved like a stable compound and did not alter in content of water. The suggestion is made that this material may be represented in nature by the mineral xanthosiderite ($Fe_2O_3.2H_2O$).

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[1] Roscoe, H. E., and Schorlemmer, C., A treatise on chemistry, vol. 2, pp. 1197 et seq., 1913.

[2] Muck, Zeitschr. Chemie, 2d ser., vol. 4, p. 41, 1868. Cited by Roscoe, H. E., and Schorlemmer, C., op. cit., p. 1222.

[3] Tommasi, D., Ricerche sulle formole di costitutione dei composti ferrici; Parte prima, Idrati ferrici, Florence, 1879. Also see Deutsche chem. Gesell. Ber., vol. 12, pp. 1929, 2334, 1879.

[4] Van Bemmelen, J. M., Rec. trav. chim., vol. 7, pp. 36–119, 1889.

[5] Ruff, O., Ueber das Eisenoxyd und sein Hydrate: Deutsche chem. Gesell. Ber., vol. 34, pp. 3417 et seq., 1901.

Ruff concludes from these data (1) that red colloidal ferric hydroxide under ordinary conditions is a colloid of indefinite composition, but that under high pressure and rising temperature it may change in a short time to various definite hydroxides; (2) that yellow ferric hydroxide is very probably a definite chemical compound that contains various amounts of adsorbed water; (3) that under ordinary conditions of temperature and pressure the red colloidal ferric hydroxide is slowly dehydrated and changed to anhydrous ferric oxide, but at the same time water is taken up by the anhydrous oxide and a change occurs to the stable ferric hydroxide, limonite; (4) that pure anhydrous ferric oxide does not form from ferric hydroxides except under exceptional conditions of temperature or pressure.

Nicolardot,[1] by whom the most recent work has been done on ferric hydroxides, has come to the conclusion that six modifications of ferric hydroxide exist which are all polymers of the simplest hydroxide. They all differ in chemical and physical properties and in the content of water. Two of the hydroxides, $(Fe_2O_3)_1(H_2O)_{1.5-2}$ and $(Fe_2O_3)_1(H_2O)_{1-1.5}$, are brown and are derived from the normal sesquioxide Fe_2O_3, whereas the other four, all opalescent and yellow in color, are derived from the two anhydrides of $Fe_2(OH)_6$—$Fe_2O(OH)_4$ and $Fe_2O_2(OH)_2$. Each of these substances forms a series of hydroxides with variable water content, the hydroxides of one series being transformed into the hydroxides of another series by the elimination of water.

Hydroxides of iron of various kinds, therefore, may be formed by precipitation with alkalies or by simple oxidation and hydrolysis from different iron compounds. Thus, solutions of ferric chloride and ferric nitrate, when treated with sodium, potassium, or ammonium hydroxides, give precipitates of red colloidal ferric hydroxide. Solutions of ferrous salts when treated with alkaline hydroxides give precipitates of light bluish-green ferrous hydroxide, which upon oxidation changes to yellow ferric hydroxide. Yellow ferric hydroxide is also formed by oxidation and hydration of ferrous carbonate and in the rusting of metallic iron. Freshly precipitated iron rust consists chiefly of ferric hydroxide but usually contains considerable quantities of ferrous hydroxide and ferrous carbonate.[2] When dried and exposed to atmospheric oxidation it soon loses its ferrous iron and consists entirely of ferric hydroxide, with the approximate composition $2Fe_2O_3.3H_2O$.

In some solutions of iron salts, such as ferrous or ferric sulphate, as well as certain iron salts of organic acids, iron may be precipitated by oxidation and hydrolysis (for the ferrous salts) or by hydrolysis alone (for the ferric salts) not as hydroxide, but in the form of basic salts. When a ferric sulphate solution is treated with an excess of alkali, as ammonium hydroxide, ferric hydroxide is precipitated. When, however, the precipitation is incomplete various basic ferric sulphates are formed. The same is true when a solution of ferric sulphate is boiled or when a solution of ferrous sulphate is allowed to oxidize in the air. Among the common basic ferric sulphates thus formed which are said to exist is $FeSO_4(OH).7H_2O$, which is decomposed by water to form the insoluble salt $Fe_3SO_4(OH)_4.5H_2O$. Several of the basic sulphates occur as minerals, being formed by the oxidation of iron sulphides.[3] Among these are vitriol ocher ($FeSO_4(OH)_4.2Fe(OH)_3H_2O$), copiapite ($Fe_2(SO_4)_3.Fe_2(SO_4)_2(OH)_2.10H_2O$), and fibroferrite ($2Fe_2(SO_4)_2(OH_2.Fe_2SO_4(OH)_4.24H_2O$).

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[1] Nicolardot, M. P., Recherches sur le sesquioxyde de fer: Annales chimie et physique, 8th ser., vol. 6, p. 334–393, 1905.

[2] Moody, G. T., The rusting of iron: Chem. Soc. Jour., vol. 89, pp. 720 et seq., 1906.

[3] Roscoe, H. E., and Schorlemmer, C., op. cit., pp. 1214 et seq.

Pickering,[1] who has done some work on the constitution of basic ferric sulphate, states that only one basic ferric sulphate exists and that it has the formula $Fe_2(SO_4)_3.5Fe_2O_3.xH_2O$, in which x ranges from 8 to 40. The molecular weight ranges from 1,341.34 to 1,916.10, according to the amount of water present.

The reason for these varying results is probably to be found in the fact that the precipitate which forms varies with the nature of the solution, the temperature, and the manner of precipitation. It probably consists of a mixture of one or more of the possible ferric hydroxides with one or more basic ferric sulphates and the proportion of each present varies under different conditions of precipitation.[2]

Mixed precipitates of all degrees of oxidation and hydration probably form under different conditions, the degree of complexity varying with the treatment. Thus simple boiling would result in the formation of a larger proportion of basic ferric sulphates, and treatment with alkalies would result in the formation of larger amounts of ferric hydroxides.

The further hydrolysis of basic ferric sulphates results in the formation of the stable ferric hydroxide, limonite.

Several of the iron salts of organic acids, such as iron acetate, iron oxalate, and iron lactate, give precipitates of flocculent basic salts. The precipitation results from simple oxidation, heating, or treatment with alkalies.

A solution of iron acetate, when treated with alkalies or when evaporated or boiled, gives a red flocculent precipitate, consisting probably of a mixture of ferric hydroxides and basic ferric acetates. The amount of ferric hydroxide present in the precipitate increases with temperature, with the strength of the precipitant, and with the time allowed for precipitation. When a solution of iron acetate is boiled in the presence of alkaline acetates, ferric hydroxide rather than basic ferric acetate is said to be precipitated.[3] A number of basic ferric acetates have been described, among which are $Fe(C_2H_3O_2)(OH)_2$, $Fe(C_2H_3O_2)_2OH$, and $Fe_2(C_2H_3O_2)_2(OH)_4+2Fe_2O_3$.[4] Herz[5] found that the basic ferric acetate, $FeC_2H_3O_2(OH)_2$, is precipitated from solutions of pure ferric acetate ($Fe(C_2H_3O_2)_3$) when heated for 10 hours or more at a temperature of 44° C., and also from impure ferric acetate solutions when allowed to stand at ordinary temperature or when boiled for a short time. Under the latter conditions no precipitation occurred from pure solutions. This basic ferric acetate is a fine yellow colloidal precipitate. Often ferric hydroxide ($Fe(OH)_3$) is said to form with it as small, brown, shining crystals.

A solution of iron oxalate upon treatment with alkalies also gives a brownish-red flocculent precipitate, which is probably a mixture of ferric hydroxides and basic ferric oxalates. An iron oxalate solution when boiled leaves a yellowish-brown salt with the composition $Fe_2(C_2O_4)_3.18Fe(OH)_3$, but when the solution is only heated to 100° C. the precipitate is $Fe_2(C_2O_4)_3.2Fe(OH)_3+4H_2O$, showing an increase of $Fe(OH)_3$ with the increase in temperature.[6]

Iron lactate upon treatment with alkalies gives a flocculent brownish-black precipitate, doubtless a mixture of ferric hydroxides and basic ferric lactates.

Comparatively little work has been done heretofore on the constitution of basic ferric compounds precipitated from solutions of organic iron salts and very little definite information is available with regard to these compounds. In general the precipitates formed are probably of indefinite composition, due to the variable content of water and to the varying amounts of ferric hydroxides mixed with them. As in the precipitation from solutions of ferrous and ferric sulphate the precipitates which form in solutions of organic iron salts vary in composition according to the conditions of precipitation.[2] If precipitation takes place through the agency of a strong alkali, such as sodium hydroxide (NaOH), more ferric hydroxide is liable to be intermixed with the basic ferric salts than if a weaker alkali, such as ammonium hydroxide (NH_4OH), is responsible for the precipitation. Likewise the reaction with a weak alkali would result in the formation of relatively more ferric hydroxide than would result from simple boiling. It seems probable that more than one basic compound of each of the organic iron salts may exist. Thus there are probably several basic ferric acetates or basic ferric oxalates and these vary in quantity relatively to each other and to the ferric hydroxides in precipitates formed under different conditions. Care must be taken, however, in drawing conclusions from analyses of precipitates, because even if but one ferric hydroxide and but one basic salt of a given organic acid were present, their changing ratios under varying conditions might counterfeit the presence of other compounds in these mixtures.

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[1] Pickering, S. W., On the constitution of molecular compounds; the molecular weight of basic ferric sulphate: Chem. Soc. Jour., vol. 43, pp. 182 et seq., 1883.

[2] Hunter, W. H. (Department of Chemistry, University of Minnesota), personal communication.

[3] Beilstein, F., Handbuch der organischen Chemie, Auflage 3, Band 1, pp. 405–406, 1893.

[4] Scheurer-Kestner, M. A., Sur quelques nouvelles combinaisons du fer et sur l'atomicité de cet élément: Soc. chim. Paris Bull., vol. 5, pp. 342–352, 1863; Mémoire sur une nouvelle classe de sels de fer, et sur la nature hexatomique du ferricum: Annales chimie et physique, 3d ser., vol. 63, pp. 422–447, 1861.

[5] Herz, W., Ueber den Verlauf der Zersetzung des Ferriacetats: Zeitschr. anorg. Chemie, Band 20, pp. 16–20, 1899.

[6] Beilstein, F., Handbuch der organischen Chemie, Auflage 3, Band 1, p. 644, 1893.

In solutions of organic iron salts of oxyacids, such as iron citrate, iron tartrate, or iron malate, basic ferric salts do not precipitate, because in these salts the iron forms part of an "inner complex salt." This is true also of salts of many of the acids which occur in the "composite" called humic acid, and is the reason why such salts may be carried in solution for long periods.

In the formation of sedimentary iron-bearing deposits in nature the precipitation of ferric hydroxide is mainly from ferrous solutions and occurs when these solutions come in contact with the oxygen of the atmosphere. The precipitation may result chemically from oxidation alone, but as a rule iron bacteria aid in the reaction. To some extent ferric hydroxide is also probably precipitated from ferric solutions which in nature are mainly solutions of organic salts, and here also iron precipitating bacteria may aid in the deposition.

The hydroxide precipitated from solutions of ferrous salts is generally the stable yellow ferric hydroxide of fairly definite chemical composition, whereas that precipitated from ferric solutions is generally the red colloidal hydroxide, which, however, in time may change to the stable hydroxide, $2Fe_2O_3.3H_2O$, as shown by Ruff.[1]

The most common form in which iron occurs in solution in natural waters is as ferrous bicarbonate, but ferrous or ferric sulphates probably occur, as well as salts of organic acids, which have generally been included under the terms ferrohumates and ferrihumates.

Ferrous bicarbonate may be derived from many different iron minerals. It is taken into solution through the agency of carbonic acid (H_2CO_3) and retained in solution by excess carbon dioxide. Such solutions may remain in circulation underground for long periods and eventually come to the surface as iron springs or seepages and may be carried by streams to lakes or lagoons. Upon the removal of the excess carbon dioxide and exposure to the atmospheric oxygen, oxidation and hydration take place according to the following reaction:[2]

$$4FeCO_3+3H_2O+2O=2Fe_2O_3.3H_2O+4CO_2$$

This reaction may perhaps be better stated in two steps, thus:

$$FeCO_3+H_2O=Fe(OH)_2+CO_2$$
$$4Fe(OH)_2+2O=2Fe_2O_3.3H_2O+H_2O$$

The flocculent yellowish-brown precipitate of ferric hydroxide ($2Fe_2O_3.3H_2O$) that is formed drops to the bottom, where it accumulates or where a part or all of it may become mixed with mud containing organic matter and be reconverted to ferrous carbonate. A part of the yellowish-brown precipitate may consist of iron in the more hydrated forms, such as $Fe_2O_3.2H_2O$ and $Fe_2O_3.3H_2O$. In this way the mixture of various ferric hydroxides and of ferrous carbonate in bog ores is accounted for. The iron sulphide and iron sulphate locally present in the deposits may be formed by the action of H_2S, given off by the decaying organic matter, on ferrous carbonate or by precipitation from iron sulphate solutions.

Iron sulphate is present in solution in meteoric waters owing to the decomposition of sulphides of iron or to the action of sulphuric acid on other iron minerals. The iron present in this form may be precipitated by simple oxidation as a mixture of ferric hydroxides and basic ferric sulphates, or by reaction with calcium carbonate present in solutions as ferrous carbonate, which then may be oxidized to limonite. Van Hise says that basic ferric sulphate may be precipitated from ferrous sulphate solution according to the following reaction:[1]

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[1] Ruff, O., op. cit.

[2] Van Hise, C. R., A treatise on metamorphism: U. S. Geol. Survey Mon. 47, p. 826, 1904.

$$12FeSO_4+6+(x+9)H_2O= \\ Fe_2(SO_4)_3.5Fe_2O_3.xH_2O+9H_2SO_4$$

In reality, however, the reactions which take place are probably much more complex and the result is a mixture of compounds rather than a single basic salt.

The reaction between ferrous sulphate and calcium carbonate to form ferrous carbonate is as follows:[2]

$$FeSO_4+CaCO_3=CaSO_4+FeCO_3$$

The calcium sulphate is deposited as gypsum, $CaSO_4.2H_2O$, and the ferrous carbonate may be oxidized to ferric hydroxide according to the reaction given above. In the presence of abundant oxygen the two reactions might occur almost simultaneously thus:

$$4FeSO_4 \xrightarrow[CaCO_3+H_2O+O]{} 2Fe_2O_3.3H_2O+CaSO_4. \\ 2H_2O+CO$$

If ferric sulphate is present in solution the precipitation of ferric hydroxides may occur thus:

$$Fe_2(SO_4)_3 \xrightarrow[CaCO_3+H_2O]{} 2Fe_2O_3.3H_2O+CaSO_4. \\ 2H_2O+CO$$

The occurrence of iron in solution in natural waters as salts of organic acids has received but little study, and the literature with reference to it is largely speculative. It is commonly supposed that the iron is in the form of soluble salts of certain little-known soil acids termed humic acids. It does not seem impossible, however, that it may also be carried as salts of other organic acids known to be present in the soil, such as formic acid, lactic acid, butyric acid, citric acid, or tartaric acid.

The iron which is present in solution in the form of organic salts upon precipitation is probably largely thrown down as ferric hydroxide together with various insoluble organic ferric compounds, which, however, in a comparatively short time will also change to ferric hydroxide. According to Aschan,[3] who has studied this subject, the principal organic iron salts occurring in natural waters are salts of humic acids, such as ferrohumates and ferrihumates. He believes that humic acids are the principal constituents of the soluble derivatives of humus, which he calls humus hydrosols (gels in colloidal solution). Humus hydrosols are of unknown and variable composition and are supposed to contain, besides humic acids, various other soil substances such as humates of different composition. They are believed to play an important part in the decomposition of rocks and minerals, as well as in the precipitation of such substances as iron and aluminum. The humus hydrosols are the materials which impart the deep-brown color to streams and lakes in regions of abundant vegetation. By decomposition they change to carbon dioxide and ammonia.

Aschan found that if ferric salts were present within certain narrow limits of concentration, in waters containing humus hydrosols, insoluble ferrihumates were deposited but that above or below this concentration only soluble salts were formed. He found also that if ferrous salts instead of ferric salts were present, no precipitation took place, soluble ferrohumates being formed, which, however, if present in the proper concentration might by oxidation change to insoluble ferrihumates.

The action of humus hydrosols in the formation of lake and bog iron ores is supposed by Aschan to be as follows: When the soluble humus substances are taken into solution by ground waters some of the humic acids in them immediately begin to react chemically on the mineral constituents of the rocks through which the waters percolate and form soluble humates of different bases, among them iron. These humates are supposed to form food for microorganisms and the microorganisms are believed to aid substantially in rock decay. Besides aiding in the decay of rocks humus hydrosols are believed to aid in the precipitation of iron and other substances from solution. When ferric or ferrous salts are in solution in water containing humus hydrosols ferrihumates or ferrohumates are formed. Ferrohumates are soluble, but under certain conditions of concentration and oxygen content insoluble ferrihumates are formed and these are precipitated directly. The soluble ferrihumates and ferrohumates may have their organic portion utilized as food by microorganisms and the ferric hydroxide is then precipitated. Thus insoluble ferrihumates and ferric hydroxide are believed to occur together in lake and bog iron ores, and this is supposed to explain the presence of organic carbon in these ores.

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[1] Van Hise, C. R., op. cit., p. 826.

[2] Moore, E. J., The occurrence and origin of bog iron deposits in the district of Thunder Bay, Ontario: Econ. Geology, vol. 4, p. 535, 1910.

[3] Aschan, Ossian, Die Bedeutung der wasserlöslichen Humusstoffe (Humussole) für die Bildung der See- und Sumpferze: Zeitschr. prakt. Geologie, Jahrg. 15, pp. 56–62, 1907.

Sjögren[1] believes that the principal agents for the solution of iron in nature are sulphuric acid, carbon dioxide, and organic acids. Sulphuric acid is formed by the decomposition of sulphides, and carbon dioxide and organic acids are formed mainly from decomposing organic matter. The decomposition of organic matter in the absence of oxygen results in the formation of hydrocarbon combinations such as humus, which when acted upon by ammonia or alkalies yield humic acids. This action withdraws oxygen from surrounding mineral compounds, in this matter reducing ferric oxide to ferrous oxide, which then forms soluble double salts with ammonia and humic acids. These double salts may be further changed to ferrous carbonate and this substance may be oxidized to ferric hydroxide by the removal of carbon dioxide in the presence of oxygen. The iron, however, may also be precipitated directly from humic acid solutions. From sulphate solutions iron may be precipitated as basic ferric sulphate, which, according to Sjögren, is changed to ferric hydroxide by the action of ammonium or alkaline carbonates or by humus. From a mixture of humic acid and iron sulphate solutions iron may be precipitated as ferric hydroxide by the action of ammonia.

According to Beck[2] iron may also be precipitated from iron sulphate solutions by the addition of ammonium humate, which he states is always present in the brown waters of peaty regions. The precipitate formed is ferric oxide and later ferric hydroxide.

The opinions concerning the precipitation of ferric hydroxide from natural iron-bearing waters have been summarized above. Some of these opinions are largely speculative as to possible reactions which may take place under conditions such as are found in nature, but others are based on well-known chemical phenomena. Though many of the reactions mentioned in connection with the precipitation of insoluble iron compounds from solutions of iron sulphate and organic iron salts probably occur, there is little doubt that far more important than these processes is the direct precipitation from ferrous bicarbonate solutions, whether through simple oxidation and hydrolysis or through the action of iron-depositing bacteria. The nature of the action of the bacteria in the deposition of ferric hydroxide is discussed at length in a subsequent section.

The precipitation of ferric hydroxide from ferrous bicarbonate solutions takes place almost immediately after the iron-bearing waters reach the surface, where they become saturated with oxygen and lose their carbon dioxide. This accounts for the yellowish-brown ocherous scums, which occur around all springs and seepages of iron-bearing waters. However, there is no doubt that iron is also carried in solution by surface streams whose waters are apparently rich in oxygen. In this manner iron in solution reaches lakes, lagoons, and marshes, where it is precipitated and forms bog and lake ores. In what form the iron is carried under these conditions it is difficult to say. Perhaps enough carbon dioxide occurs in these waters to permit the carrying of appreciable amounts of iron as ferrous bicarbonate, or perhaps the iron is carried in the form of organic iron salts. The equilibrium between the solvent carbon dioxide and the ferrous bicarbonate in solution is a subject which requires more thorough investigation.

Besides the iron which is carried in solution by surface streams probably a considerable amount of light flocculent ferric hydroxide, which has been formed where the iron-bearing solutions first reach the surface, is carried in suspension by the current and is deposited when quiet water is reached.

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[1] Sjögren, H., Ueber die Entstehung der schwedischen Eisenerzlager: Geol. Fören. Stockholm Förh. 13, p. 373, 1891. Reviewed by R. Scheibe in Zeitschr. prakt. Geologie, 1893, pp. 434–437.

[2] Beck, R., The nature of ore deposits, vol. 1, pp. 101–103, translated by W. H. Weed, 1905.

The dehydration of iron deposits from their original form as ferric hydroxide to the final form of slightly hydrated ferric oxide is a slow process and results from several conditions.

According to Ruff,[1] as already stated, the red colloidal ferric hydroxide suffers gradual dehydration and becomes anhydrous ferric oxide. The anhydrous oxide, however, in the presence of moisture becomes hydrated again and alters to the stable form, limonite, and remains in this form. Other investigators, however, report that ferric hydroxide left for several years under water at ordinary temperatures became dehydrated and crystalline.[2]

Spring[3] says that ferric hydroxide spontaneously loses its water if the iron is not combined chemically with some other substance. The yellow color would thus indicate the presence of alumina, lime, or magnesia. He believes that limonite is not a stable hydroxide and will give up its water when not in equilibrium with other oxides present.

Pressure has in some places been an important factor in the dehydration of iron-bearing deposits and in other places heat and pressure both have been active. In some deposits the pressure may have been due simply to deep burial, but in other deposits deformational earth movements have been an added factor. It seems reasonable to suppose that long periods of time, aided by pressure due to deep burial, might result in at least a partial dehydration of iron-bearing deposits.

Various impurities besides iron salts are commonly precipitated with ferric hydroxide from solution, such as silica, phosphates, alumina, and manganese oxides. Silicic acid may be carried in solution in the colloidal form or as alkaline silicates.[4] The alkaline silicates are acted upon by carbon dioxide in solution and silica is thrown down. Colloidal silicic acid is deposited by evaporation. Phosphorus, probably carried in solution in the form of soluble phosphates, may be precipitated either as calcium phosphate or as iron phosphate. Manganese, which may be present in solution in considerable amount, is thrown down upon oxidation as a mixture of manganese oxides. Some alumina also is probably precipitated with the ferric hydroxide, and, as previously stated, gypsum is thrown down with bog ores by the reaction of ferrous sulphate with calcium carbonate.

FORMATION OF DEPOSITS OF FERROUS CARBONATE.

Ferrous carbonate is known to occur in two forms—the insoluble carbonate ($FeCO_3$) and the soluble carbonate or bicarbonate (hypothetical formula, $Fe(HCO_3)_2$). The insoluble carbonate occurs only in the solid form and is either crystalline or fine grained and amorphous. It is made in the laboratory by precipitating a solution of green vitriol ($FeSO_4.7H_2O$) with sodium bicarbonate and heating the mixture for 12 to 36 hours at a temperature of 150° C.[5] In this manner microscopic rhombohedra of ferrous carbonate ($FeCO_3$) are formed. When a cold solution of pure ferrous sulphate is treated with sodium carbonate, a flocculent white precipitate of ferrous carbonate is formed, which becomes dirty green in color on exposure to air, due to the absorption of oxygen and the evolution of carbon dioxide, and soon changes to ferric hydroxide. If the precipitate is washed in the absence of oxygen it may be obtained pure and colorless, but usually it takes the form of a gray powder, which oxidizes readily to ferric oxide on exposure to air.

Ferrous bicarbonate occurs in many natural waters, being taken into solution by the action of carbon dioxide on ferrous carbonate. It is not known in the dry state, for on precipitation in the absence of oxygen it changes to insoluble ferrous carbonate ($FeCO_3$) and in the presence of oxygen it is precipitated as ferric hydroxide.

The supposition that iron is carried in solution in natural waters principally as the bicarbonate, or at least as a soluble carbonate, is probably fairly well founded, because abundant iron is found in many places in solution in waters in which there is no other acid radicle present except the bicarbonate. Ferrous bicarbonate remains in solution for an indefinite length of time, as long as the waters carry an excess of carbon dioxide in the free state. As soon, however, as waters become depleted of free carbon dioxide precipitation in one of the various forms already mentioned will take place, the particular form depending on the conditions under which deposition occurs. When abundant oxygen is present precipitation will occur in the form of ferric hydroxide. When no oxygen is present and at the same time carbon dioxide is removed precipitation occurs in the form of iron carbonate. This form of precipitation takes place in marshes or shallow bodies of water where vegetation and decaying organic matter are abundant. The free carbon dioxide is supposed to be removed in part by diffusion and in part through absorption by plants, and at the same time the waters are depleted of their oxygen by decaying organic matter. Even if part of the iron is precipitated in the first place as ferric hydroxide, that substance would probably be reduced and altered to carbonate on becoming mixed with muds rich in organic matter. The deposition of ferrous carbonate in bogs, therefore, is very similar to that of bog-ore deposits of ferric hydroxide, except that under these conditions the abundance of decaying organic matter results in the precipitate remaining in the ferrous form or being changed to the ferrous form.

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[1] Ruff, O., op. cit.

[2] Wittstein, Vierteljahresschrift für Pharmacie, Band 1, p. 277. Cited by Moore, E. J., op. cit., p. 537.

[3] Spring, W., Ueber die eisenhaltigen Farbstoffe sedimentären Erdboden und über den wahrscheinlichen Ursprung der rothen Felsen: Neues Jahrb., 1899, Band 1, pp. 47–62.

[4] Sjögren, H., op. cit.

[5] Roscoe, H. E., and Schorlemmer, C., A treatise on chemistry, vol. 2, p. 1247, 1913.

If the iron is thrown down as ferric hydroxide and sinks to the bottom it may become mixed with more or less organic matter as well as fine clastic sediments, and thus a considerable thickness of material may be built up.[1] The reducing action of the organic matter in the muds which changes the ferric hydroxide to ferrous carbonate is due to the removal of oxygen required for the oxidation of carbon compounds. As such places are below the level of ground water the conditions for the oxidation are imperfect, owing to the scarcity of free oxygen. The carbon, therefore, takes part of its oxygen from the ferric hydroxide, reducing it to ferrous hydroxide, which reacts with carbon dioxide to form ferrous carbonate. The reaction, on the assumption that carbon is the reducing agent, is as follows:

$$\left\{\begin{array}{l} 2Fe_2O_3.3H_2O+C=4FeO+CO_2+3H_2O \\ 4FeO+4CO_2=4FeCO_3 \end{array}\right.$$

From ferrous sulphate solutions ferrous carbonate may be precipitated by calcium carbonate[2] according to the reaction:

$$FeSO_4+CaCO_3=FeCO_3+CaSO_4$$

In the absence of oxygen and free carbon dioxide the ferrous carbonate thus formed will be precipitated along with the calcium sulphate.

According to Van Hise and Leith,[3] ferrous silicate which has been precipitated from ferrous sulphate or other iron solutions by alkaline silicates, as explained elsewhere (p. 73), may, in the presence of abundant carbon dioxide, be partly or entirely changed to ferrous carbonate, according to the following reaction:

$$FeSiO_3+CO_2=FeCO_3+SiO_2$$

In the presence of excess carbon dioxide the ferrous carbonate will go into solution but may become deposited by the removal of free carbon dioxide.

Various impurities may be precipitated with ferrous carbonate, such as calcium carbonate, magnesium carbonate, and manganese carbonate.[4] Of these impurities calcium carbonate, which is almost invariably present in solution in iron-bearing waters, is by far the most important. Magnesium carbonate, however, is commonly present and manganese carbonate may be conspicuous locally. Silica also occurs abundantly in many places with ferrous carbonate. It may be deposited in the form of clastic grains along with clay and other materials, but generally it is in the amorphous form as chert, and in that form it may be either a chemical precipitate or it may be derived from the casts of minute siliceous organisms living in the water. Phosphorus probably remains in solution under conditions which cause precipitation of iron carbonate.

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[1] Van Hise, C. R., op. cit., p. 827.

[2] Moore, E. J., The occurrence and origin of some bog iron deposits in the district of Thunder Bay, Ontario: Econ. Geology, vol. 5, pp. 528–537, 1910.

[3] Van Hise, C. R., and Leith, C. K., The geology of the Lake Superior region: U. S. Geol. Survey Mon. 52, p. 526, 1911.

[4] Vogt, J. H. L., Marmor und Eisenerze von Dunderland: Bildung der Eisenerzlager: Dunderlandsdalens jernmalmfelt, 1894, p. 106. Reviewed in Zeitschr. prakt. Geologie, 1895, pp. 37–39.

FORMATION OF DEPOSITS OF IRON SILICATE.

Various iron silicates, such as amphibole, pyroxene, biotite, garnet, epidote, olivine, and chlorite, which occur in igneous and metamorphic rocks have already been mentioned. Most of them are complex silicates containing iron, aluminum, magnesium, calcium, and other elements. Besides these there are a number of secondary hydrous iron silicates which form under ordinary conditions of sedimentation, such as glauconite, greenalite, thuringite, chamosite, berthierine, and bavalite. The occurrence and association of these have also been described.

In ordinary sedimentary iron-bearing deposits, such as bog ores, ferrous silicates are stated by Van Hise to be formed by reaction between colloidal silica and ferrous compounds.[1] When ferric hydroxide is precipitated in the presence of abundant organic matter and becomes mixed with it in the mud it is reduced to ferrous oxide, as already explained. Van Hise says that if under these circumstances abundant colloidal silica is present it may unite with the ferrous oxide and form ferrous silicate, generally more or less hydrated. The formation of hydrous ferrous silicate under these conditions, rather than ferrous carbonate, is said to be probably dependent on the law of mass action.[1] It seems to be extremely questionable, however, whether ferrous silicate is ever formed in this manner.

Van Hise and Leith[2] give a discussion of the formation of iron silicate from iron solutions by the action of alkaline silicates on ferrous salts. The iron silicate greenalite ($Fe(Mg)O.SiO_2.nH_2O$), of the Lake Superior iron-bearing formations, is supposed to have been thus precipitated.

Various laboratory experiments were performed to show the reactions between silicic acid or alkaline silicates and iron salts. The silicic acid used was produced from alkaline silicates by treatment with hydrochloric acid, so that the solutions contained sodium chloride as well. They thus resembled sea water, in which the deposition of greenalite is believed to have taken place. Van Hise and Leith come to substantially the following conclusions concerning the formation of iron silicates:[3]

1. A solution of ferrous salt when boiled with silicic acid prepared as above stated [by neutralizing sodium silicate or water glass ($Na_2O.3SiO_2$) with hydrochloric acid] produces (in the absence of air) no precipitate, showing that silicic acid and a ferrous salt do not react to form ferrous silicate.

2. Ferrous sulphate reacts directly with solutions of silicates of the alkalies, producing a granular precipitate corresponding in composition to the water glass used in the precipitation. Thus:

$$FeSO_4+Na_2O.3SiO_2=FeO.3SiO_2+Na_2SO_4$$

The precipitate formed in this manner is composed of ferrous silicate and free silica. When the relative proportions of alkali and silica are varied in the water glass the amount of silica precipitated with the ferrous silicate also varies. If a soluble magnesium salt is present it will be precipitated with the iron as magnesium silicate. The ferrous silicates produced were as follows: (1) $FeO.3SiO_2$, formed from hot or cold solutions with ferrous salt in excess, (2) $FeO.5SiO_2$, formed from cold solutions with water glass in excess, and (3) $FeO.10SiO_2$, formed from hot solutions with water glass in excess. When $FeO.3SiO_2$ is boiled with water silica is taken into solution and the precipitate which remains approaches $FeO.SiO_2$ in composition. However, this composition is not reached, for the iron oxidizes, rendering the remaining silica soluble. If allowed to stand and dry, out of contact with the air, the hydrous ferrous silicates also gradually lose water.

3. The ferrous silicates require neutral or slightly alkaline conditions for precipitation. They are soluble in acids or strong alkalies.

4. In the presence of oxygen varying amounts of ferric oxide form with the ferrous silicate.

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[1] Van Hise, C. R., A treatise on metamorphism: U. S. Geol. Survey Mon. 47, p. 827, 1904.

[2] Van Hise, C. R., and Leith, C. K., op. cit., pp. 521–526.

[3] Idem, p. 521.

5. Ferrous silicates may be precipitated by alkaline silicates from various ferrous salts, such as ferrous sulphate, ferrous bicarbonate, and ferrous chloride. The reaction for ferrous chloride would be

$$FeCl_2+Na_2SiO_3=FeSiO_3+2NaCl$$

6. In the presence of an excess of carbon dioxide ferrous silicate may be changed to ferrous carbonate.

The precipitates of hydrous ferrous silicates formed as described above are flocculent and of a green color. According to Van Hise and Leith they develop on settling a granular texture similar to the greenalite occurring in the Lake Superior iron formation. This phenomenon is stated to be due probably to the surface tension between the precipitate and the liquid.

The commonly quoted hypothesis of the formation of the iron silicate glauconite is that of Murray and Renard which has already been mentioned.[1] According to this hypothesis the iron silicate is not precipitated as such but is formed by secondary processes. Shells of dead organisms, mainly Foraminifera, drop to the bottom and become filled with fine mud containing iron. This mud is acted upon by the organic matter of the organism in the presence of sulphates in the sea water resulting in the reduction of the iron present in the mud to sulphide. This sulphide later oxidizes to ferric hydroxide setting free sulphuric acid, which removes the alumina in solution and sets free colloidal silica. The colloidal silica in turn reacts upon the hydroxide, and in the presence of potassium salts, derived from other minerals, forms glauconite.

FORMATION OF DEPOSITS OF IRON SULPHIDE.

Sulphides of iron may be precipitated from either organic or inorganic solutions of iron salts by simple chemical reaction with other constituents in solution or with materials in contact with the solutions. Precipitation may also take place by the reduction of iron sulphate in solution through the action of organic matter, bacteria, or other reducing agent, or by the action of hydrogen sulphide, liberated from decaying organic matter, on iron carbonate or other iron salts in solution.

The following are the principal sulphides of iron:[2]

	Formula.
Ferrous sulphide, troilite	FeS
Magnetic iron sulphide, pyrrhotite	$Fe_{11}S_{12}$
Ferric sulphide	Fe_2S_3
Iron disulphide, pyrite, marcasite, and melnikowite	FeS_2

Ferrous sulphide, or iron monosulphide, occurs in nature as a constituent of certain sediments containing abundant organic matter and laid down under strongly reducing conditions. Such deposits occur in the Black Sea and elsewhere and have already been described. Ferrous sulphide is also found as the mineral troilite, a constituent of some meteorites. It is easily formed in the laboratory[2] by the direct union of the elements iron and sulphur, (1) by burning iron in sulphur vapor; (2) by heating iron filings and sulphur together in a red hot crucible, or (3) by stirring a white-hot iron rod in molten sulphur. In this manner ferrous sulphide forms as a yellowish crystalline metallic substance. When iron filings and sulphur are mixed with water and rubbed to a paste, black ferrous sulphide is produced with the evolution of heat. It is also formed as a black amorphous mass by the action of ammonium sulphide on solutions of ferrous salts or by the reduction of ferric oxide or its salts in the presence of sulphates and decomposing organic matter. Ferrous sulphide may also be formed by action of hydrogen sulphide, liberated from decaying organic matter, on iron carbonate or other iron salts in solution.

Magnetic iron sulphide is a mixture of the monosulphide and the sesquisulphide of iron. It occurs abundantly in metalliferous veins as the mineral pyrrhotite. It does not form under ordinary conditions of sedimentation but is a product of hot magmatic solutions.

Ferric sulphide is not known to occur in nature. In the laboratory[2] it is produced by the action of ammonium sulphide on solutions of ferric salts in an excess of alkali. When the ferric salt is in excess a mixture of ferrous sulphide and sulphur is formed. Ferric sulphide is formed also by the action of hydrogen sulphide on ferric hydroxide in the presence of traces of ammonia. It may be formed dry by gently heating sulphur and iron together or by the action of hydrogen sulphide on ferric oxide at a temperature not above 100° C. When thus formed the material is a yellow nonmagnetic mass.

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[1] Murray, J., and Renard, A. F., *Challenger* Rept., Deep-sea deposits, p. 383, 1891.
Clarke, F. W., The data of geochemistry, 3d ed.: U. S. Geol. Survey Bull. 616, p. 516, 1916.

[2] Roscoe, H. E., and Schorlemmer, C., Treatise on chemistry, vol. 2, pp. 1232-1236, 1913.

Disulphide of iron occurs abundantly in nature as the minerals pyrite and marcasite and locally as melnikowite.[1] Pyrite forms beds and lenses interlayered with sedimentary and metamorphic rocks and occurs disseminated or as concretions in sedimentary rocks, such as shale, limestone, and quartzite. It is also abundantly disseminated through igneous rocks and occurs in association with metalliferous ore deposits, both in those of magmatic origin and those of meteoric origin. In general it is one of the most widespread iron minerals and occurs in rocks of various kinds. Marcasite occurs in metalliferous veins. It is not as common as pyrite.

Iron disulphide is said to be formed in nature by the action of organic matter on water which contains iron sulphate in solution and generally occurs as spherical, botryoidal, or stalactitic masses. It also is common in peat and coal, replacing organic matter and taking the form of roots, wood, etc.[2]

In the laboratory iron disulphide is formed by heating ferrous sulphide with sulphur or by passing hydrogen sulphide over oxides or chlorides of iron heated to redness. It is formed also as yellow crystalline pyrites when carbon bisulphide vapor acts upon heated ferric oxide; when a mixture of ferric oxide, sulphur, and salammoniac is heated slowly above the volatilization temperature of salammoniac; or when ferric chloride is heated with phosphorus pentasulphide.

Van Hise[3] says that iron disulphide may be formed in sedimentary iron-bearing deposits by the reduction of basic ferric sulphate, which, as has been explained, results from the oxidation of ferrous sulphate solutions and may be deposited together with ferric hydroxide in the bottoms of lagoons. The reduction is due to decaying organic matter, which requires abundant oxygen and takes part of it from the basic ferric sulphate, which is thus reduced to disulphide of iron. As there is more iron present than is required for combination with the sulphur, it is believed that the excess iron may combine with carbon dioxide or perhaps with silica and form ferrous carbonate or ferrous silicate.

Much of the iron sulphide occurring in sedimentary rocks has doubtless been formed by chemical processes, but the chemical action is for the most part the result of the decomposition of organic matter by bacteria. Decomposing organic matter may cause the formation of iron sulphide (1) by the direct reduction of iron sulphate in solution, owing to the removal of oxygen by the oxidation of carbon, or (2) by the action of hydrogen sulphide, produced during the decomposition, on various iron salts in solution. Much of the iron sulphide also is deposited directly by the bacteria which have the power of reducing iron sulphates to sulphide and which have already been described.

As bacteria are largely responsible for the deposition of iron sulphide in nature, the discussion of this subject is therefore taken up in connection with the biologic deposition of iron.

DEPOSITION OF IRON BY BIOLOGIC AGENCIES.

FORMATION OF DEPOSITS OF FERRIC HYDROXIDE.

As bacterial processes are becoming better understood their relations to various phenomena in geology are found to be of increasing importance. Not only do they aid in the decomposition of rocks, as has already been shown, but they are important factors in the formation of certain rock and mineral deposits, notably those of calcium carbonate, calcium phosphate,[4] ferric hydroxide, and iron sulphide.

Drew,[5] Kellerman, Vaughan, and others who have recently investigated modern calcium carbonate deposits of the sea bottom have come to the conclusion that bacterial processes have played an important part in the formation of the vast beds of marine, nonfossiliferous limestone of various geologic ages.

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[1] Doss, Bruno, Zeitschr. prakt. Geologie, Jahrg. 20, pp. 453–483, 1912.

[2] Roscoe, H. E., and Schorlemmer, C., op. cit., p. 1234.

[3] Van Hise, C. R., op. cit., p. 828.

[4] Blackwelder, Eliot, The geologic rôle of phosphorus: Am. Jour. Sci., 4th ser., vol. 42, pp. 285–298, 1916.

[5] Drew, G. H., On the precipitation of calcium carbonate by marine bacteria and on the action of denitrifying bacteria in tropical and temperate seas: Carnegie Inst. Washington, Dept. Marine Biology, Papers from Tortugas Laboratory, vol. 5, pp. 7–45, 1914.

The generally accepted hypothesis for the formation of nonfossiliferous limestones has been that they were formed as chemical precipitates, the precipitation being ascribed to the action of ammonium carbonate, an end product of the decomposition of nitrogenous organic matter, on calcium sulphate present in sea water, according to the following equation:[1]

$$(NH_4)_2CO_3+CaSO_4=CaCO_3+(NH_4)_2SO_4$$

Decay-producing bacteria are of great importance in this process, for it is due largely to their activity that ammonia is produced, and this unites with carbon dioxide in solution to form ammonium carbonate.

Drew in his recent work has shown that widely distributed marine denitrifying bacteria are also of great importance in the precipitation of calcium carbonate. He claims that these bacteria have largely caused the extensive accumulations of chalky mud in the vicinity of the Bahamas and the Florida Keys which are being formed at the present time, and that they also play an important part in the cementation of fragments of coral and shells into coralline rock. He suggests that bacterial action has been an important factor in the past in the formation of chalks and limestones of different geologic ages.

The principal denitrifying bacterium active in this precipitation is a minute, actively motile bacillus with rounded ends, named *Bacterium calcis* by Drew but found by Kellerman to have a single polar flagellum and to belong to the genus *Pseudomonas*.[2] It is a facultative anaerobe and has the power of reducing nitrates to nitrites. The nitrites thus formed gradually disappear with the formation of some ammonia but without the perceptible formation of free nitrogen.

The principal culture medium used by Drew in the laboratory for preparing cultures of this organism consisted of calcium malate (or calcium acetate), potassium nitrate, sodium phosphate, and sea water. Agar and gelatin were used in conjunction with these salts in the preparation of solid media. In these artificial media the reduction of the nitrates begins in a very short time and is accompanied by the precipitation of calcium carbonate.

Drew states that the precipitation of calcium carbonate by these bacteria is in part caused by the greater alkalinity of the solution which results from the breaking down of nitrates and setting free of the bases during the process of denitrification but is probably due in part also to the direct breaking up of calcium salts (chiefly of organic acids), the calcium then uniting with carbon dioxide to form calcium carbonate.

Kellerman and Smith,[3] who have recently further studied the activity of the microorganisms that precipitate calcium carbonate, believe that the precipitation may take place in any of the following ways:

1. The reduction of nitrates results in the formation of nitrites and finally of ammonia, which unites with the carbon dioxide present to form ammonium carbonate, and this reacts upon calcium sulphate to form calcium carbonate according to the equation already given. Ammonia may also be formed by the decomposition of protein.

2. Ammonia itself may react on calcium bicarbonate present in the sea water and precipitate calcium carbonate according to the following equation:

$$Ca(HCO_3)_2+2NH_4OH= CaCO_3+(NH_4)_2CO_3+2H_2O$$

3. The bacteria feed on organic acids and as far as calcium salts of organic acids are present in sea water these are broken up and the calcium unites with free carbon dioxide and is precipitated as calcium carbonate. For this process denitrifying organisms also may be necessary.

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[1] Murray, J., and Hjort, J., The depth of the ocean, 1912. Murray, J., and Irvine, R., On coral reefs and other carbonate of lime formations in modern seas: Roy. Soc. Edinburgh Proc., vol. 17. 1889.

[2] Vaughan, T. W., Geological investigations in the Bahamas and southern Florida: Carnegie Inst. Washington, Ann. Rept. Dept. Marine Biology, Yearbook 13, pp. 227–233, 1915.

[3] Kellerman, K. F., and Smith, N. R., Bacterial precipitation of calcium carbonate: Washington Acad. Sci. Jour., vol. 4, No. 14, pp. 400–402, 1914.

Vaughan[1] states that the deposits of calcareous oolite in Florida and the Bahamas have probably resulted from bacterial activity. The calcium carbonate, which is precipitated in a finely divided state, largely as aragonite, forms spherulites, which by accretion or by accumulation around various nuclei build up oolitic grains, and these gradually accumulate to form beds.

The formation of the deposits of calcium carbonate thus outlined shows considerable analogy to the precipitation of iron compounds by bacterial action, which is briefly summarized in the following paragraphs.

Of the various accumulations of iron compounds in nature due to processes of sedimentation, biologic agencies are known to be important only in the deposition of those of ferric hydroxide and ferrous sulphide. Indirectly, however, microorganisms may be of importance in the deposition of ferrous carbonate and ferrous silicate as well.

That biologic processes are important in the formation of iron-ore deposits is no new idea. It was first advanced by Ehrenberg eighty years ago and since then it has been reiterated at various times by observers who have had occasion to study the so-called iron bacteria. The facts regarding the activity of these organisms in the precipitation of ferric hydroxide, however, have been treated in geologic literature only in a very general way and in many reports only vague references are made to them.

It is now well known that not only iron-precipitating bacteria but various other iron-precipitating organisms exist, some belonging to the algae and fungi and others belonging to the protozoa. Whether the term "iron-precipitating organisms" is really applicable to many of the forms is still an open question. It is not definitely known whether certain of the organisms actually aid in the precipitation of iron compounds or whether they simply act as gatherers of iron compounds precipitated by chemical processes. It is certain, however, that many of the forms do aid in the precipitation, among them being certain of the iron thread bacteria which precipitate ferric hydroxide from ferrous bicarbonate solutions, the various microorganisms which precipitate ferric hydroxide and basic ferric salts from solutions of certain organic iron salts, and the sulphate-reducing and hydrogen sulphide forming microorganisms, which precipitate ferrous sulphide from iron-bearing solutions.

In the formation of ferrous carbonate and ferrous silicate deposits organic material is of importance to the extent that its decay results in the reduction to the ferrous form or the retention in the ferrous form of any iron compounds present. In promoting this decomposition bacteria are of importance. The precipitation of such ferrous compounds in the form of ferrous carbonate or ferrous silicate may take place by the absorption of solvent carbon dioxide by plants, by rapid diffusion of carbon dioxide, or by reaction of the ferrous compounds with alkaline silicates.

The activities of bacteria in depositing ferric hydroxide have been described quite fully in the foregoing pages, so that only a general statement concerning them is necessary. According to present knowledge it may be said that, as regards physiologic activities, three principal varieties of these bacteria exist—(1) those which precipitate ferric hydroxide from solutions of ferrous bicarbonate and use the carbon dioxide liberated and the energy produced during oxidation for their life processes, (2) those which do not require ferrous bicarbonate for their life processes but which cause the deposition of ferric hydroxide when either inorganic or organic iron salts are present, and (3) those which attack organic iron salts, using the organic acid radicle as food and precipitating ferric hydroxide, or basic ferric salts, which are gradually changed to ferric hydroxide. These organisms can not utilize inorganic iron salts.

The first group has at least one representative and this is a very common and very important form—*Spirophyllum ferrugineum*. It is probable, however, that *Gallionella ferruginea*, which is a near relative of *Spirophyllum*, also belongs to this group, as well as other so-called iron bacteria whose physiology has not yet been studied in detail. Lieske[1] has shown that *Spirophyllum ferrugineum* will not grow in media in which ferrous bicarbonate is not present, and that other iron salts can not take the place of ferrous bicarbonate in culture media for *Spirophyllum*. He found also that the smaller the amount of organic material present in the solutions the better is its growth. In solutions containing an abundance of carbon dioxide but in which organic matter was entirely absent, *Spirophyllum ferrugineum* was found to grow profusely. The culture solutions for *Spirophyllum* which Lieske used contained metallic iron and carbon dioxide for the formation of ferrous bicarbonate, and small amounts of ammonium and magnesium sulphates, potassium chloride, calcium nitrate, and potassium phosphate to supply other elements required by the organisms for growth.

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[1] Vaughan, T. W., Preliminary remarks on the geology of the Bahamas, with special reference to the origin of the Bahaman and Floridian oolites: Carnegie Inst. Washington, Dept. Marine Biology, Papers from Tortugas Laboratory, vol. 5, pp. 49–54, 1914.

In his experiments Lieske substituted other metals, such as manganese, lead, zinc, tungsten, copper, etc., for iron, but found that with none of these metals did growth take place. He attempted also to substitute ferric salts as well as other ferrous salts for ferrous bicarbonate but found that these did not induce any growth of *Spirophyllum*. However, he found that if ferrous bicarbonate were present in addition to some other iron salts the latter did not impair the growth. Atmospheric oxygen was found to be absolutely necessary for the growth of *Spirophyllum*, and when oxygen was absent no growth took place. The optimum temperature was found to be 5° to 6° C., no growth taking place in solutions above 27° C.

From these results it was concluded that *Spirophyllum ferrugineum* will grow in entirely inorganic media, that it does not require organic carbon for food but will take its carbon from ferrous bicarbonate, and that besides carbon it requires iron and oxygen. It is difficult to see why the organism finds it necessary to take carbon from the ferrous bicarbonate rather than utilize the carbon dioxide in solution in the water, unless, as is probable, the oxidation of ferrous carbonate is necessary as a source of energy.

The physiology of *Crenothrix polyspora*, *Clonothrix fusca*, and *Siderocapsa treubii* has not been thoroughly studied, and the exact conditions under which these organisms thrive are not known. *Crenothrix polyspora* grows abundantly in pure well waters, which, besides calcium and magnesium carbonates and a small amount of iron, contain few impurities. These conditions are very similar to those under which *Spirophyllum* and *Gallionella* thrive and would seem to indicate that *Crenothrix* requires very little if any organic matter. *Crenothrix polyspora* apparently does not grow profusely in marsh waters, where abundant organic matter is present. *Clonothrix fusca* resembles *Crenothrix* in its occurrence. *Siderocapsa*, on the other hand, more nearly resembles *Leptothrix* in its habits, occurring in marshes attached to living or dead vegetable matter and, like *Leptothrix*, probably requires organic matter for growth.

Of the second group of iron-precipitating bacteria the principal forms are *Leptothrix ochracea* (*Chlamydothrix ochracea*), and *Cladothrix dichotoma*. *Leptothrix ochracea* occurs abundantly in iron-bearing waters of iron springs and marshes, and *Cladothrix dichotoma* is a common soil organism, apparently being but little influenced in its distribution by the presence of iron compounds.

While the occurrence of *Leptothrix ochracea* in nature is undoubtedly controlled to a large extent by the presence of iron salts, it has been shown by Molisch[2] that in the laboratory *Leptothrix* will thrive abundantly on iron-free culture media consisting of distilled water with 1 to 2 per cent peptone. If iron is present in the culture solutions, however, *Leptothrix* will show better development and will deposit ferric hydroxide in its sheath. It has a great affinity for manganese compounds as well, and if manganese salts are present it will deposit hydrated manganese oxide in its sheath.

The form in which the iron or manganese occurs apparently makes little difference in the development of *Leptothrix*. In the natural waters in which *Leptothrix* grows the iron is probably largely in solution as ferrous bicarbonate with perhaps subordinate amounts as ferrous sulphate and organic iron salts. In the laboratory Molisch used mainly organic salts of iron and manganese, such as iron ammonium citrate, iron ammonium tartrate, and manganpeptone, and obtained profuse growth.

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[1] Lieske, R., Beiträge zur Kenntnis der Physiologie von *Spirophyllum ferrugineum* (Ellis): Jahrb. wiss. Botanik, Band 49, 91–127, 1911; also Centralbl. Bakteriologie, Abt. 2, Band 31, pp. 296–298, 1911.

[2] Molisch, Hans, Die Eisenbakterien, p. 45, 1910.

Like *Spirophyllum ferrugineum*, *Leptothrix ochracea* is an aerobic organism, but unlike *Spirophyllum* it requires organic matter as a source of carbon. Molisch states that he has never been able to cultivate it in a medium free from organic matter. The optimum temperature for the growth of *Leptothrix ochracea* is 23° to 25° C., and the temperature limits are 5° to 40° C.

Cladothrix dichotoma is a widespread soil organism, occurring in association with *Streptothrix*, *Actinomycetes*, and other thread bacteria. It grows abundantly on most of the ordinary culture media used for soil bacteria, and if iron is present in them it will deposit ferric hydroxide on its sheath.

The third group of organisms probably includes numerous species, nearly all of which are lower bacterial forms. These bacteria use the acid radicle of organic iron salts as a source of food, and this results in the precipitation of ferric hydroxide or basic ferric salts. Many of the forms probably attack only one or two organic salts, perhaps iron citrate, iron tartrate, or iron malate, but others may be able to use a large number of organic iron salts, including salts of soil acids, such as humates. At present very little definite information is at hand concerning the importance of this process in nature, and even in the laboratory this phenomenon has been studied only in a very general way. It is quite possible that many of the already well-known soil bacteria have the power of thus precipitating insoluble ferric compounds from solution from one or more organic iron salts. I have isolated several forms which actively precipitate insoluble ferric salts from solutions of ferric ammonium citrate and have cultivated them on solid media. I have also succeeded in causing precipitation of insoluble ferric salts by microorganisms from iron oxalate, iron lactate, and other organic iron salts but have not yet been successful in growing any of the precipitants of these organic iron salts on solid media.

It seems probable that the insoluble ferric compounds precipitated as a result of this activity are mixtures of ferric hydroxides and various basic organic iron salts. After precipitation, however, bacterial activity probably continues, and as a result more and more of the organic acid radicle is doubtless removed from the precipitate until finally only ferric hydroxide is left.

The importance of this group of organisms in the formation of iron-ore deposits of course depends entirely upon the extent to which organic compounds of iron, such as humates, are carried in solution in natural waters. Some investigators believe that large amounts are carried in this way, but others believe that the amounts thus carried are insignificant and that practically all the iron in solution in natural waters is in the form of ferrous bicarbonate. From observations regarding the conditions under which iron is retained in solution in natural waters, notably the fact that surface waters, which are apparently saturated with oxygen and carry little carbon dioxide, commonly contain appreciable quantities of iron, it seems reasonable to believe that iron is carried in other forms besides that of bicarbonate. What these forms are will have to be determined by further work including careful analyses of iron-bearing waters. It is extremely difficult to detect organic iron salts when present in such small quantities as would occur in natural waters.

As both chemical and biologic processes of various kinds are admittedly active in the precipitation of ferric hydroxide, the question as to which process is predominant in the formation of sedimentary iron-ore deposits and iron-bearing formations must be solved largely by field evidence. As many of the present deposits of iron carbonate were probably originally laid down as ferric hydroxide and were subsequently reduced, this question not only concerns the present deposits of ferric oxide but many of the deposits of ferrous carbonate and perhaps of ferrous silicate as well.

From the geologist's point of view, the important things to be considered with reference to bacteria that deposit ferric hydroxide are as follows: (1) Their distribution, whether widespread or limited; (2) the importance of their activity in natural iron-bearing waters, as compared with simple oxidation; (3) the conditions under which they are active; (4)

the part which they have played in the formation of iron-ore deposits in the past.

It has been repeatedly mentioned that iron thread bacteria are found practically wherever iron-bearing waters occur, whether stagnant or flowing. Some varieties are more abundant in iron springs, wells, and mines, where the water is relatively pure, but others are common in marshes and lagoons where organic matter is abundant. I have examined ocherous scums deposited from iron-bearing waters from many different localities and have almost invariably found that they consisted mainly of sheaths of iron thread bacteria associated locally with granular and colloidal ferric hydroxide. In fact, I have examined only one specimen of ocherous scum in which I did not find bacterial remains. This was obtained from the hot springs near Ainsworth, British Columbia, and was sent to me by Mr. A. D. Wheeler, who says that the temperature of the spring is 112° F. The material is yellowish brown in color and in the dry state is a fine powder. Under the microscope it is seen to consist of minute rounded granules, some spherical, some elongated, and some irregular in shape. The granules are light-colored, semitransparent, but with a dark border as though they might be hollow casts.

One of the most common forms found, and one which occurs in relatively pure surface as well as underground waters, is *Spirophyllum*. I have found this form in nearly all the iron springs which I have examined and also in the waters of several mines and in iron-bearing well waters. It may occur in pure culture or it may be associated with any of the other forms of iron thread bacteria. *Gallionella* is not so common as *Spirophyllum*, and I have found it only in mines, where it is commonly associated with *Spirophyllum* and *Leptothrix*.

Leptothrix is almost as widespread as *Spirophyllum* and usually is the predominant form where it is found. It is common in iron springs and marshes, where in many places it forms large yellowish-brown gelatinous masses. At one locality I found it in a mine occurring in gelatinous masses on the sides and bottoms of drifts near openings where iron-bearing waters issued. With it occurred also *Gallionella* and *Spirophyllum*. This occurrence of iron thread bacteria in mine drifts at depths as great as 300 feet and probably much deeper is extremely interesting and to my knowledge has not been mentioned in the literature. It opens the interesting possibility that not only may these bacteria be instrumental in the formation of surface bog ores, but they may play a part in the formation of certain underground deposits of limonite such as those which occur in the Appalachian region.

Crenothrix and *Clonothrix* occur more rarely than the other iron thread bacteria. I have found *Crenothrix* only in well water that has passed through city distributing pipes. Molisch, however, states that in Europe it has been found also in surface waters that contain iron. *Clonothrix* is said to live under the same conditions as *Crenothrix*. I know of its occurrence only on the walls of certain underground aqueducts that conduct water from lakes to city reservoirs.

Though the work concerning the distribution of iron thread bacteria has perhaps not yet been as extensive as might be wished, it has been sufficient to indicate that wherever accumulations of ferric hydroxide occur at the present time under normal conditions they are largely due to the action of iron thread bacteria.

To what extent the lower iron-precipitating bacteria present in soil and natural waters are instrumental in the formation of deposits of ferric hydroxide it is as yet impossible to say. These organisms do not leave residues that are readily identifiable, as are those left by thread bacteria, and besides it is not known to what extent iron is carried in solution in forms that could be utilized by them. In many of the iron scums much granular and colloidal ferric hydroxide is associated with the casts of iron thread bacteria, and it is possible that this material may in part have resulted from the action of the lower bacterial types. At any rate it is of considerable interest to note that these organisms are almost universally present in soil and natural water.

The abundant occurrence of iron thread bacteria on articles of metallic iron that are rusting under water is also interesting. It shows that these organisms are readily distributed in nature and are not confined to certain places where iron-bearing waters are constantly present. I have seen *Spirophyllum* attached to iron articles that were rusting in small temporary pools of water in localities where it was very difficult to account for its presence unless it had been carried by non iron-bearing waters for long distances. Generally when such pools of water dry up porous tubercles of iron rust are formed on the surface of the metallic iron. These tubercles may be several inches in diameter at the base and consist largely of dried casts of iron thread bacteria. See fig. 13 and Pl. IX, *B*.)

The question as to the relative importance of microorganisms and simple oxidation in the precipitation of ferric hydroxide under natural conditions is a difficult one to answer. I have allowed samples of water that contain natural ferrous bicarbonate in solution to stand in vessels so that the iron present was precipitated and formed a deposit at the bottom. Upon examination this deposit was found to consist of a mixture of casts of iron thread bacteria and granular ferric hydroxide, the granular ferric hydroxide being somewhat more abundant. The granular material probably resulted from direct oxidation, although there is a possibility that lower forms of iron-precipitating bacteria assisted. However, even though simple oxidation may be more effective in the precipitation of ferric hydroxide from ferrous bicarbonate solutions, the fact that deposits of the precipitate found in nature are made up largely of bacterial remains indicates the importance of microorganisms in the accumulation if not in the precipitation of the ferric hydroxide.

Other questions which arise are what percentage of the iron is carried in other forms besides that of ferrous bicarbonate, and what is the relative importance of organisms and simple oxidation in the precipitation of ferric hydroxide from such iron solutions. By present analytical methods it is practically impossible to tell ordinarily in what form the bases are carried in solution. It has been the common practice to combine certain bases with certain acid radicles without reference to the most probable combinations of salts present. Not only is it difficult, however, to determine in what manner different bases and acid radicles are combined, but also to determine the presence of small quantities of certain acid radicles, especially those of organic salts, in solution. Iron may not all be present in solution as ferrous bicarbonate or ferrous sulphate but may occur in forms which resist oxidation for a long time or may even require special conditions for any precipitation at all to take place.

The conditions under which iron bacteria are active in nature seem to be extremely varied. They thrive in surface as well as in underground waters and in stagnant as well as in running waters. Temperature also, within moderate limits, seems to have little effect on the growth of iron-depositing bacteria, although most of them seem to prefer cold waters to warm waters. In the hot spring near Ainsworth, British Columbia, having a temperature of 112° F., there are apparently no remains of iron-depositing bacteria present in the ocherous deposits, but in ordinary iron springs both *Leptothrix* and *Spirophyllum* thrive during the winter as well as during the summer, and *Crenothrix* is present in city water pipes throughout the year. Lieske states that the optimum temperature for *Spirophyllum* is 5° to 6° C.[1] I have found 9° to 10° C. to be a common temperature in iron springs containing growths of iron-depositing bacteria.

The amount of iron required in solution for most iron-depositing bacteria seems to be extremely small. *Crenothrix* is abundant in the water of the city supply of Madison, Wis., which contains only 1.8 parts of ferric oxide (Fe_2O_3) per million, and *Leptothrix* was found to grow profusely in iron spring water containing 5.2 parts of ferric oxide (Fe_2O_3) per million. The latter amount of iron imparts a strong iron taste to the water, but I have found both *Leptothrix* and *Spirophyllum* in water in which the iron present was hardly noticeable to the taste.

The amount of organic matter in solution is somewhat of a limiting factor in the growth of iron-depositing bacteria. Some forms, like *Leptothrix*, require a certain amount of organic carbon present, but other forms, such as *Spirophyllum*, thrive best in water containing little or no organic carbon. It is probable, also, that other materials in solution, such as certain inorganic salts, affect the growth of iron-depositing bacteria. Iron-depositing thread bacteria have never been found in sea water and probably do not occur there on account of the high percentage of certain inorganic salts present.

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[1] Lieske, R., op. cit.

The question as to what part iron-depositing bacteria have played in the formation of iron-ore deposits in the past can not be settled by direct field evidence, for bacterial remains are comparatively short-lived in ocherous accumulations of iron oxide, and the slightest metamorphism will completely obliterate all traces of them. Schorler[1] has shown that even in the ferric hydroxide crusts forming inside of water pipes in cities which use iron-bearing waters, the form of the bacterial remains composing them is preserved only for a comparatively short time in the outer layers of the crust and the inside layers consist of compact limonite from which all traces of bacterial forms have vanished.

In some of the recent bog iron ore deposits, however, casts of the organisms are still to be seen, although there are many in which not a trace of them remains. Thus out of 61 specimens of bog ore examined by Molisch[2] he found only four which showed abundant remains of iron thread bacteria. It is probable that much of the granular ferric hydroxide which composes bog iron ore was originally in the form of casts of thread bacteria, but doubtless also much of it is chemically precipitated material, which has perhaps formed in quiet waters or which has had a chance to accumulate because of becoming attached to bacterial threads or other objects. Perhaps a part of this granular material may have been precipitated by lower bacteria as well, such as *Siderocapsa* and other forms already described, and thus would probably be indistinguishable from the chemically precipitated material.

Both chemical and biologic processes seem to have been important in the formation of iron-ore deposits in the past, and the question as to which has predominated in the formation of any particular deposit must be solved by a study of the conditions at the time of deposition. The method of attack involves a study not only of the sedimentation, but of climate, depth of water, relation to land areas, nature of currents, nature of materials carried in solution, and many other factors. It is only through a complete study of all the conditions involved that a conclusion may be arrived at as to the most probable manner of deposition of any individual deposit.

FORMATION OF DEPOSITS OF FERROUS SULPHIDE.

The deposition of ferrous sulphide usually takes place in inclosed or partly inclosed bodies of water in which decaying organic matter is abundant. The organic matter is decomposed largely by the action of microorganisms, and during the decomposition hydrogen sulphide, ammonia, hydrogen, methane, and other gases are liberated. Iron salts are probably brought in by streams from surrounding regions. Under strongly reducing conditions and in the presence of hydrogen sulphide these become converted to hydrous ferrous sulphide and are precipitated.

In the formation of deposits of ferrous sulphide, under ordinary conditions of sedimentation, the ferrous sulphide may be precipitated from iron-bearing solutions directly by the reduction of iron sulphates, sulphites, or thiosulphates by microorganisms, or it may be precipitated by the action of hydrogen sulphide on ferrous salts in solution, the hydrogen sulphide being formed by bacterial action either from decaying sulphur-bearing organic matter, from salts of sulphurous or sulphuric acid by reduction, or from free sulphur by reduction.[3] The precipitation of ferrous sulphide occurs under reducing conditions and usually in the presence of abundant decaying organic matter. The action is therefore largely dependent on the presence of various reducing and decay-producing organisms.

Besides forming as a direct precipitate from ferrous solutions, ferrous sulphide may be formed by the reduction of originally precipitated ferric hydroxide under the action of decaying organic matter in the presence of sulphates.

I have already discussed the precipitation of ferrous sulphide in some detail, so that it will not be necessary to state more than the essentials of the process here. Probably the most interesting of the microorganisms concerned in this activity are those which reduce various salts of sulphurous and sulphuric acid and which are known to be widely distributed in nature. They live under anaerobic conditions and obtain oxygen, which they require for the oxidation of carbon within their cells, from sulphates, sulphites, and thiosulphates, with the result that these compounds are reduced to sulphides. Ferrous sulphide may thus be directly formed by the reduction of iron sulphate.

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[1] Schorler B., Die Rostbildungen in den Wasserleitungsröhren: Centralbl. Bakteriologie, Abt. 2, Band 15, pp. 564–568, 1906.

[2] Molisch, Hans. Die Eisenbakterien, pp. 59–65, Jena, 1910.

[3] Omelianski, W., Der Kreislauf des Schwefels, in F. Lafar's Handbuch der technischen Mycologie, Band 3, pp. 214–220, 1904–5.

When sulphides of other metals, such as calcium or magnesium, are formed in an analogous manner, they may be further acted upon by carbon dioxide in the presence of water and changed to carbonates and hydrogen sulphide. The hydrogen sulphide may then react on ferrous salts present in the water, especially ferrous bicarbonate, and precipitate ferrous sulphide. The equation for this reaction has already been given.

Hydrogen sulphide is abundantly produced by the decay of sulphur-bearing proteins. The power to form hydrogen sulphide from proteins during decomposition is common to all putrefying bacteria, of which there are innumerable varieties and which are abundant everywhere. The precipitation of ferrous sulphide (FeS) through the activity of these organisms becomes merely a question of the presence of dead organic matter and of iron salts in solution.

The reduction of sulphur to hydrogen sulphide takes place in the presence of decomposing organic matter. It is probably due to secondary processes that result from various reactions which take place under these conditions. The hydrogen sulphide thus formed will precipitate ferrous sulphide from ferrous solutions which may be present.

The production of hydrogen sulphide through the action of bacteria is important and widespread.[1] In the presence of abundant hydrogen sulphide in the water and the resultant decrease of oxygen the higher organisms frequently disappear entirely and the organisms which thrive in abundance are infusoria, radiolaria, oscillaria, diatoms, *Chroococcus*, and abundant bacteria such as sulphur bacteria and various anaerobes. Of these the sulphur bacteria are especially interesting, as they oxidize hydrogen sulphide to free sulphur and sulphates and in this manner obtain energy for their life processes. This action is analogous to the oxidation of ferrous carbonate to ferric hydroxide by some iron thread bacteria.

In the Weissowo salt sea in the Charkow government, Russia, Nadson found the following content of hydrogen sulphide per liter of water:[1]

Content of hydrogen sulphide, in cubic centimeters per liter of water, from Weissowo salt sea, Russia.

Depth of 16 meters	5.91
Depth of 18 meters	88.31
Depth of 18.7 meters	184.96

According to Lebedinzeff the Russian deep-sea expedition of 1891 found throughout the Black Sea at depths below 200 to 400 meters an increasing amount of hydrogen sulphide in solution.[2]

Content of hydrogen sulphide, in cubic centimeters per liter, of water from the Black Sea.

Depth of 213 meters	0.33
Depth of 427 meters	2.22
Depth of 2,026 meters	5.55
Depth of 2,528 meters (bottom)	6.55

This high content of hydrogen sulphide is typical of the Black Sea and does not extend into the Sea of Marmora or the Mediterranean. Its presence is due to the action of anaerobic bacteria on organic matter in the presence of sulphates of the sea water. Sulphate and thiosulphate reducers have also been found in Black Sea muds. According to Andrussow,[3] the presence of hydrogen sulphide in the water of the Black Sea is due to the fact that on account of the rapidly increasing density of the water with depth only the upper 170 meters have circulating currents, the rest being stationary. This is not true of other seas where oxygen is carried to depths and the hydrogen sulphide formed is soon oxidized by sulphur bacteria to sulphates or reacts with iron salts present, causing the precipitation of ferrous sulphide.

The precipitated ferrous sulphide usually does not form pure deposits but becomes more or less mixed with fine clastic material and organic matter and forms a black mud. The black mud of the limans that occur along the shores of the Black Sea and elsewhere in southeastern Russia upon exposure to oxygen turns gray, due to the oxidation of ferrous sulphide, but upon being again covered with brine black spots appear and soon the whole mass becomes black, being again reduced to ferrous sulphide through the activity of organisms which are able to live in concentrated salt solutions. These organisms liberate hydrogen sulphide and also ammonia and amino bases. Under the influence of hydrogen sulphide in alkaline solution ferrous sulphide is precipitated from the iron salts present as a black, colloidal, plastic, hydrous deposit, which impregnates the muddy mass of organic and clastic material.

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[1] Omelianski, W., op. cit., pp. 220–224, 1904–1906.

[2] Lebedinzeff, A., Soc. naturalistes Odessa Travaux, Band 16, 1891. Cited by Omelianski, W., op. cit.

[3] Andrussow, N., Acad. sci. St.-Pétersbourg Mém., Band 1, p. 1, 1894. Cited by Omelianski, W., op. cit.

The gray oxidized liman mud when sterilized keeps indefinitely. However, upon being covered with water and reinoculated with fresh mud, with stream water, or with pure cultures of sulphate-reducing bacteria it again takes on a black color. This shows that living organisms are responsible for the reduction.

It has been shown also that at the same time that hydrated ferrous sulphide gel separates out in muds silica gel frequently separates out and forms thin films (less than 4 micra in thickness) around finely divided particles of hydrated ferrous sulphide gel, thus producing minute grains.[1] The granular texture thus produced is often characteristic of ferrous sulphide deposits.

BIBLIOGRAPHY.

Adler, Oscar, Ueber Eisenbakterien und ihrer Beziehung zu den therapeutisch verwendeten natürlichen Eisenwässern: Centralbl. Bakteriologie, Abt. 2, Band 11, pp. 215–219, 277–278, 1903–4.

Andrussow, N., Vorläufiger Bericht über die naturwissenschaftlichen Ergebnisse der Tiefseeuntersuchungen im Schwarzen Meere: Imp. russk. geog. Obschch. Izvestia, vol. 26, pp. 400–402, 1890.

——— Contribution à la question de l'origine de l'hydrogène sulfuré des eaux de la Mer Noire: Idem, vol. 28, p. 370, 1892.

——— Sur la fermentation hydrosulfureuse dans les eaux de la Mer Noire: Acad. sci. St.-Pétersbourg Mém., vol. 1, p. 1, 1895 [1894].

Andrussow, N., Le Mer Noire: Cong. géol. internat., 7^e sess., Guides des exc., 1897.

Aschan, Ossian, Die Bedeutung der wasserlöslichen Humusstoffe (Humussole) für die Bildung der See- und Sumpferze: Zeitschr. prakt. Geologie, Jahrg. 15, pp. 56–62, 1907.

Beijerinck, M., *Spirillum desulphuricans:* Centralbl. Bakteriologie, Abt. 2, Band 1, p. 1, 1895; idem, Band 11, p. 595, 1904.

Benecke, Wilhelm, Bau und Leben der Bakterien, pp. 160–161, 180–181, 202–204, 487–498, Leipzig and Berlin, 1912.

Beythien, Hempel, and Kraft, Beiträge zur Kenntnis des Vorkommens von *Crenothrix polyspora* in Brunnenwässern: Zeitschr. Untersuchungen der Nahrungs und Genussmittel, 1904, Heft 4, p. 215.

Brown, J. C., Deposits on pipes and other channels conveying potable waters: Inst. Civil Eng. Proc., vol. 156, pt. 2, pp. 1–17, 1904.

Brussilowsky, Soc. balnéologie d'Odessa Compt. rend. séances, No. 4, 1892.

Büsgen, M., Kulturversuche mit *Cladothrix dichotoma:* Deutsch. bot. Gesell. Ber., Band 12, pp. 147–152, 1894.

Cohn, F. J., Ueber den Brunnenfaden (*Crenothrix polyspora*) mit Bemerkungen ueber die mikroskopische Analyse des Brunnenwassers: Beitr. Biologie Pflanzen, Band 1, Heft 1, pp. 108–131, 1875.

——— Untersuchungen ueber Bakterien, II: Beitr. Biologie Pflanzen, Band 1, Heft 3, p. 185, 1875.

Doss, Bruno, Ueber die Natur und Zusammensetzung des in Miocaenen Tonen des Gouvernements Samara auftretenden Schwefeleisens: Neues Jahrb., Beilage Band 33, pp. 662–713, 1912.

——— Melnikowit, ein neues Eisenbisulphid, und seine Bedeutung für die Genesis der Kieslagerstätten: Zeitschr. prakt. Geologie, Jahrg. 20, pp. 453–483, 1912.

Ehrenberg, C. G., Vorläufige Mittheilungen ueber das wirklige Vorkommen fossiler Infusorien und ihre grosse Verbreitung: Poggendorff's Annalen, Band 38, pp. 213–227, 1836.

——— Die Infusionstierchen als vollkommene Organismen, pp. 169–170, Leipzig, 1838.

——— Gallionella ferruginea: Taylor's Scientific Mem., vol. 1, pt. 3, p. 402, 1847.

Ellis, David, On the discovery of a new genus of thread bacteria (*Spirophyllum ferrugineum* Ellis): Roy. Soc. Edinburgh Proc., vol. 27, pt. 1, pp. 21–34, 1907.

——— Iron bacteria and their connection with stone decay: Roy. Philos. Soc. Glasgow Proc., 1907.

——— A contribution to our knowledge of the thread bacteria, I: Centralbl. Bakteriologie, Abt. 2, Band 19, pp. 502–518, 1907.

——— A preliminary notice of five new species of iron bacteria: Roy. Soc. Edinburgh Proc., vol. 28, pt. 5, pp. 338–342, 1908. Reviewed in Centralbl. Bakteriologie, Abt. 2, Band 25, p. 311, 1910.

——— A contribution to our knowledge of the thread bacteria, II: Centralbl. Bakteriologie, Abt. 2, Band 26, pp. 321–329, 1910.

---

[1] Jegunow, M., Schwefeleisen und Eisenoxydhydrat in den Boden der Limane und des Schwarzen Meeres: Annales géol. min. Russie, vol. 2, pp. 171–174, 1897. Cited by Doss, Bruno, Neues Jahrb., Beilage Band 33, p. 687, 1912.

Ellis, David, On the new genus of iron bacteria, *Spirophyllum ferrugineum* (Ellis): Roy. Soc. Edinburgh Proc., vol. 31, pt. 4, pp. 499–504, 1911.

——— An investigation into the life history of *Cladothrix dichotoma* (Cohn): Roy. Soc. Proc. *B*, vol. 85, pp. 344–358, 1912.

——— The iron bacteria: Science Progress, vol. 10, pp. 374–392, January, 1916.

Fischer, A., The structure and functions of bacteria, trans. by A. Coppen Jones, p. 69, Oxford, 1900.

Harder, E. C., Iron bacteria: Science, new ser., vol. 42, pp. 310–311, 1915.

Hayes, A. O., Wabana iron ore of Newfoundland: Canada Geol. Survey Mem. 78, pp. 67–92, 1915.

Hinze, G., Eisenbakterien im Zerbster Grundwasser Kanal: Festschrift zur Feier des fünfzigsten jährigen Bestehens des naturwissenschaftlichen Vereins zu Zerbst, pp. 34–40, 1912. Reviewed in Centralbl. Bakteriologie, Abt. 2, Band 35, p. 77, 1912.

Höflich, K., Kultur und Entwicklungsgeschichte der *Cladothrix dichotoma* Cohn: Oesterr. Monatsschrift Tierheilkunde, Band 25, pp. 4–23, 46–64, 1901.

Issatschenko, B. L., Ueber die Ablagerung von schwefelgem Eisen in den Bakterien: Jardin bot. St.-Pétersbourg Bull., vol. 12, pp. 134–139, 1913.

Jackson, D., A new species of *Crenothrix:* Am. Micros. Soc. Trans., vol. 23, 1902.

Jegunow, M., Schwefeleisen und Eisenoxydhydrat in den Boden der Limane und des Schwarzen Meeres: Annales géologie et minéralogie Russie, vol. 2, p. 172, 1897.

Kirchoffer, W. G., The sources of water supply in Wisconsin: Wisconsin Univ. Bull. 106 (Eng. ser., vol. 3, No. 2), 1905.

Kützing, Phycologia generalis, 1843.

——— Species algarum, 1849.

Lebedinzeff, A., Soc. naturalistes Odessa Travaux, Band 16, 1891.

——— Ebenda, Band 18, 1893.

——— Chemische Untersuchungen des Marmarameeres an den Türkischen Schiffe *Sselanik* im Jahre 1894.

Lieske, Rudolf, Beiträge zur Kenntnis der Physiologie von *Spirophyllum ferrugineum* Ellis, einem typischen Eisenbakterien: Jahrb. wiss. Botanik, Band 49, pp. 91–127, 1911. Reviewed in Centralbl. Bakteriologie, Abt. 2, Band 31, pp. 296–298, 1911.

Lipman, J. G., Microbiology of soil, in Marshall's Microbiology, pp. 288–290, Philadelphia, 1912.

Migula, W., Ueber *Gallionella ferruginea* Ehrenburg: Deutsche bot. Gesell. Ber., Band 15, p. 321, 1897.

——— System der Bakterien, Band 2, p. 1031, 1900.

Molisch, Hans, Die Pflanze in ihren Beziehungen zum Eisen, p. 71, Jena, 1892.

——— *Siderocapsa treubii* Molisch, eine neue weitverbreitete Eisenbakterie: Jardin bot. de Buitenzorg Annales, Suppl. 3, Treubfestschrift 1, pp. 29–33, 1910. Reviewed in Centralbl. Bakteriologie, Abt. 2, Band 29, p. 243, 1911.

Molisch, Hans, Die Eisenbakterien, Jena, 1910. Reviewed in Centralbl. Bakteriologie, Abt. 2, Band 29, pp. 241–243, 1911.

Montfort, W. F., Dry feed of chemicals in water purification: Am. Waterworks Assoc. Jour., vol. 2, pp. 200–206, 1915.

Moore, G. T., The deposition of iron on the mycelium of an aquatic fungus: Science, new ser., vol. 35, p. 153, 1912.

Mumford, E. M., A new iron bacterium: Chem. Soc. Jour., vol. 103, pp. 645–650, 1913.

Nadson, On hydrogen sulphide fermentation and on the action of microorganisms in the formation of black mud, St. Petersburg, 1903.

Omelianski, W., Der Kreislauf des Schwefels, in Franz Lafar's Handbuch der technischen Mykologie, Band 3, pp. 214–220, Auflage 2, Jena, 1904–5.

Phelps, E. B., Microbiology of sewage, in Marshall's Microbiology, pp. 217–218, Philadelphia, 1912.

Potonie, H., Eisenerze, veranlasst durch Tätigkeit von Organismen: Naturwiss. Wochenschrift, pp. 161–168, 1906. Reviewed in Centralbl. Bakteriologie, Abt. 2, Band 22, p. 142, 1908–9.

Rössler, O., Ueber Kultivierung von *Crenothrix polyspora* auf festem Nährboden: Archiv Pharmacie, Band 233, pp. 189–191, 1895.

——— Der Nachweis von *Crenothrix polyspora* in Trinkwasser: Deutsche med. Wochenschrift, 1906, No. 40, pp. 1628–1629.

Rullmann, W., Eisenbakterien, Cladotricheen, Streptotricheen und Actinomyceten, in Franz Lafar's Handbuch der technischen Mykologie, Band 3, Kapitel 7, Auflage 2, Jena, 1904–5.

——— Photogramme von *Crenothrix polyspora* Cohn: Centralbl. Bakteriologie, Abt. 2, Band 20, p. 1908.

——— Ueber Eisenbakterien: Centralbl. Bakteriologie, Abt. 2, Band 33, pp. 277–289, 1912.

Schorler, B., Beiträge zur Kenntnis der Eisenbakterien: Centralbl. Bakteriologie, Abt. 2, Band 12, pp. 681–695, 1904.

——— Die Rostbildungen in den Wasserleitungsröhren: Centralbl. Bakteriologie, Abt. 2, Band 12, pp. 564–568, 1906.

Schwers, Henri, Le fer dans les eaux souterraines, pp. 44–45, Paris, 1908.

——— *Megalothrix discophora*, eine neue Eisenbakterie: Centralbl. Bakteriologie, Abt. 2, Band 33, pp. 273–276, 1912.

Tolomei, G., Ueber die Veränderung eisenhaltiger Mineralwässer: Annali di farmacoterapia e chimica, vol. 18, No. 5, p. 297, 1893. Reviewed in Zeitschr. anorg. Chemie, vol. 5, p. 102, 1894.

Weidman, Samuel, and Schultz, A. R., The underground and surface water supplies of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 35, pp. 156, 217, 317, 437, 1915.

Winogradsky, S., Ueber Eisenbakterien: Bot. Zeitung, Band 46, pp. 262–270. 1888.

Zopf, W., Entwicklungsgeschichtliche Untersuchungen ueber *Crenothrix polyspora*, die Ursache der Berliner Wasserkalamität, p. 16, Berlin, 1879.

——— Zur Morphologie der Spaltpflanzen (Spaltpilze und Spaltalgen), p. 36, Leipzig, 1882.

INDEX.

Page.

- Acetate, basic ferric, precipitation of 67
- Acetic fermentation, process of 45–46
- Acids, occurrence of, in soils and waters 45, 46
  - origin of, in soils and waters 45–46
- Acknowledgments for aid 7–8
- Action, method of, by iron-depositing bacteria 5, 11–13
- Adler, Oscar, cultivation of iron-depositing bacteria by 19
- Algae, deposition of ferric hydroxide by 11
- *Anthophysa*, occurrence of 19
- Aschan, Ossian, work of, on organic salts of iron 69–70
- Austria, Carpathian Mountains, pyrite in 61

- *Bacillus M.* 7, activities of 18
  - discovery of 9
- *Bacterium calcis*, denitrifying action of 76
- Basic ferric acetate, precipitation of 67
- Basic ferric oxalates, precipitation of 67
- Basic ferric lactates, precipitation of 67
- Bavalite, occurrence of 58
- Beck, R., work of, on the precipitation of iron ores 70
- *Beggiatoa*, activities of 44
- Beijerinck, M., work of, on sulphate-reducing bacteria 42, 43
- Berthierine, occurrence of 58
- Bibliography 84–85
- Bilbao, Spain, iron carbonate deposits of 57
- Black band iron ores, nature and occurrence of 54–55
- Black muds, ferrous sulphide in 61, 62
- Black sands, nature and origin of 64
- Black Sea, hydrogen sulphide in water of 83
  - iron in mud of 61, 63
- "Blue mud," iron sulphides in 61, 62–63
- Bog iron ore, deposition of 18
  - nature and origin of 53–54
  - remains of bacteria in 82
- Bohemia, chamosite ores in 59–60
- Bridgewater Canal, Lancashire, England, bacillus from water of 39–40
- Brown, James Campbell, theory of, concerning iron-depositing bacteria 12
- Brussilowsky, work of, on sulphate-reducing bacteria 42

- Canga ores, origin of 64
- Carbohydrates, decomposition of 45–46
- Carbon dioxide, origin of 45
- Carbonate of iron, deposits of nature and origin of 54–57
  - occurrence of, in peat bogs 54
- Carbonic acid, action of, on iron 46–47
- Cellulose, decomposition of 46
- Chamosite, nature and occurrence of 58, 59–60
  - occurrence of, in Wabana iron ore 50, 51
- Chemical processes, deposition of iron by 64–75, 81
- *Chlamydothrix ferruginea. See Gallionella ferruginea.*
  - *ochracea* Migula. *See Lepidothrix ochracea* Kützing.
  - *sideropus*, holdfast of 20
- *Cladothrix dichotoma*, habit of 9–10, 78–79
  - occurrence of 19
- Clay ironstone, nature and occurrence of 54–56
- Clinton iron ore, nature and origin of 49–50
- *Clonothrix fusca*, distribution of 80
  - habit of 9–10, 78
- Cohn, F. J., theory of, concerning iron-depositing bacteria 11
- Collection of bacteria, method of 14
- Conidia, external, existence of 11
  - production and germination of 8, 15–16
- *Conidiothrix*, features of 11, 21
- Copiapite, origin of 66
- Crawford, W. G., analyses by 14, 16, 18, 33, 35
- *Crenothrix polyspora* Cohn, coating of, with ferric hydroxide 16
  - collection and cultivation of 14–15
  - distribution of 80
  - habit of 9, 78, 81
  - occurrence of 13–14
  - photomicrographs of 14, 15, 16
  - portions of threads of, plate showing 14
  - reproduction of 15–16
  - size and structure of 15
  - staining of 16
- Cultivation of iron-depositing bacteria 14–15, 18–19
  - preparation of solutions for 42–43
  - salts used in 30
  - use of plates for 34–35
- Cultures of bacteria, keeping of 18

- Decomposition of iron-bearing minerals, process of 45–48
- Deposition of iron by bacteria 75–84
  - by chemical processes 64–75
  - by mechanical processes 64
- Development of iron-depositing bacteria, time required for 26
- Dhâwar rocks, iron ore in 52
- Distribution of iron-depositing bacteria 79–80
- Disulphide of iron, formation of 75
- Doss, Bruno, explanation by, of the origin of iron sulphides in sedimentary deposits 63–64
- Drew, G. H., work of, on the precipitation of calcium carbonate 75–76
- Dunderland, Norway, iron ore in 52

- Ehrenberg, C. G., discovery of bacterial deposition of iron by 7
- Ellis, David, work of, on the mode of action of iron-depositing bacteria 12
- Experiments on precipitation of iron by bacteria 31–44

- Fats, decomposition of 46
- Federal mine, near Hazel Green, Wis., *Gallionella* and *Spirophyllum* in 22, 24–25
  - ocherous gelatinous scum from, photomicrographs of 19, 22
- Ferric ammonium citrate, absence of iron-depositing bacteria from precipitates from 32–33
  - cultures in which sterilization has prevented precipitation from, plate showing 32
  - cultures in which ferric hydroxide has been precipitated from, plates showing 27, 32
  - precipitation of iron from, by bacteria 31–36, 36–37
  - use of in culture media 30
- Ferric chloride solutions, attempts to make cultures of bacteria in 40
- Ferric citrate, precipitation of iron from by bacteria 36, 37
- Ferric hydroxide, dehydration of 71
  - deposition of, by bacteria 8, 31–40, 77–82
    - by chemical processes 64–71
    - from ground waters 48, 49–54
- Ferric hydroxides, red and yellow, preparation of 65
- Ferric oxalate, precipitation of iron from, by bacteria 36, 37
- Ferric sulphate, oxidation of 69
- Ferric sulphates, basic, formation of 66–67

Page.

- Ferric sulphide, synthesis of, 74–75
- Ferrohumates and ferrihumates, origin of, 69–70
- Ferrous ammonium sulphate solutions, attempts to make bacterial cultures in, 39
- Ferrous bicarbonate, origin and oxidation of, 68, 70, 71–72
  - solutions of, attempts to make cultures of bacteria in, 40
- Ferrous carbonate, deposition of, 71–73
  - impurities precipitated with, 72–73
- Ferrous sulphate, oxidation of, 68–69
  - solutions of, attempts to make cultures of bacteria in, 39
- Ferrous sulphide, deposition of, 40–44, 74, 82–84
  - occurrence of, 61
- Fibroferrite, origin of, 66
- Flagellates, deposition of ferric hydroxide by, 11
- Fred, E. B., acknowledgment to, 8
- Fungi, deposition of ferric hydroxide by, 11

- *Gallionella ferruginea* Ehrenberg, activities of, 77
  - description of, 23–24
  - distribution of, 80
  - habit of, 10
  - occurrence of, 22–23
  - reproduction of, 24
- Geologic importance of iron-depositing bacteria, 44–84
- Glauconite, composition and occurrence of, 57–59
  - formation of, 74
- Great Britain, iron carbonate deposits in, 54–56
- Greenalite, composition and occurrence of, 58–59
- Greensand, distribution of, 59
- Growth of bacteria, conditions required for, 81–82

- *Haplobacteria*, classification of, 8
- Hastings, E. G., acknowledgment to, 8
- Hay extract, bacteria in, precipitation of iron by, 31
- Hematite, deposition of, 49–54
- Hillcrest mine, Cuyuna iron range, Minn., *Spirophyllum* in, 26
- Humus, decomposition of, 46
- Humus hydrosols, nature and action of, 69–70
- Hunter, W. H., acknowledgment to, 8
- Hydrogen sulphide, action of, in producing ferrous sulphide, 41
  - oxidation of, 44
  - production of, by bacteria, 29, 30–31, 41, 83

- India, iron-ore deposits in, 52
- Inorganic iron solutions, precipitation of iron from, 38–40
- Investigation, scope of, 7
- Iron, distribution of, in the earth's crust, 44–45
  - soluble salts of, carriage of, by water, 46–47
    - formation of, 47
- Iron acetate, precipitation of iron from, by bacteria, 36, 37
- Iron albuminate, precipitation of iron from, by bacteria, 36, 37
- Iron bars, *Spirophyllum* in tubercles on, 26–27
- Iron-depositing bacteria, classification of, 8–11
  - lower, activities of, 29–30
- Iron lactate, precipitation of iron from, by bacteria, 36, 37
- Iron ores, types of, 48–49
- Itabirite, nature and occurrence of, 51–52
- Italy, northern, pyrite in, 61

- Jasper Peak, near Soudan, Minn., *Spirophyllum* at, 25, 26
- Judson mine, Alpha, Mich., ocherous scum from, photomicrographs of, 23
  - *Spirophyllum* in, 25

- Keeping of bacteria, 18
- Kellerman, K. F., and Smith, N. R., work of, on the precipitation of calcium carbonate, 76
- Kennedy mine, Cuyuna district, Minn., *Leptothrix*, *Spirophyllum*, and *Gallionella* in, 17–18, 22
  - material from, photomicrographs of, 18

Page.

- Lactates, basic ferric, precipitation of, 67
- Lake Kegonsa, Wis., spring near, analysis of water from, 16
  - spring near, *Leptothrix* in, 16–17
    - ocherous scum on, photomicrographs of, 17
    - precipitation of iron by bacteria in water from, 31–32
- Lake Mendota, precipitation of iron by bacteria in water from, 31, 32
- Lake ores, nature and origin of, 53–54
- Lake Superior iron region, iron carbonate deposits in, 56–57
  - ore of, nature and origin of, 51
- Laterite, fragmental, mechanical deposition of, 64
- Leith, C. K., acknowledgment to, 8
  - Van Hise, C. R., and, work of, on the formation of iron silicates, 73–74
- *Leptothrix ochracea* Kützing, cultivation of, 18–19
  - description of, 19–21
  - distribution of, 80
  - habit of, 10, 78–79, 81
  - mode of action of, 11–12, 13
  - occurrence of, 16–19
  - reproduction of, 21
- Lieske, Rudolf, cultivation of *Spirophyllum* by, 27
  - theory of, concerning iron-depositing bacteria, 12–13
- Limans, ferrous sulphide deposited in mud of, 61, 63, 84
- Limestones, deposition of, 75–77
- Limonite, Jurassic, of France and Germany, nature and origin of, 52–53
  - powder of, from tubercle of iron rust, photomicrograph of, 26
- Lower iron-depositing bacteria, activities of, 80
  - forms of, 34–35
  - habit of, 79
  - photomicrographs of, 38

- Madison, Wis., city water, analysis of, 14
  - bacteria in, precipitation of iron by, 31, 32
  - *Crenothrix polyspora* in, photomicrographs of, 14, 15, 16
  - *Gallionella*, *Spirophyllum*, and *Crenothrix* in, 22–23
  - *Spirophyllum ferrugineum* in, photomicrograph of, 22
- Magnetic iron sulphide, formation of, 74
- Manganese acetate solution, development of mold in, 36, 37
- Manganese citrate solution, development of mold in, 36, 37
- Marcasite, occurrence of, 60–61
  - origin of, 75
- Marshes, bog iron ore deposits in, 53–54
- Mechanical processes, deposition of iron by, 64
- *Megalothrix discophora*, habit of, 10
- Melnikowite, occurrence of, 61, 63
  - origin of, 75
- *Microspira aestuarii*, isolation of, 42
- Middleburg, Va., *Leptothrix* and *Spirophyllum* in spring near, 17
- Migula, W., classification of iron bacteria by, 8–9
- Minas Geraes, Brazil, itabirite in, nature and origin of, 51–52
- Minerals, iron-bearing, decomposition of, 45–48
- Minette ore, nature and occurrence of, 52–53
- Molds, development of, in precipitates from solutions of iron salts, 33, 37, 39
- Molisch, Hans, cultivation of *Leptothrix* by, 19
  - theory of, concerning iron-depositing bacteria, 12
- Montfort, W. F., cultivation of *Leptothrix* by, 19
- Muck, —, work of, on ferric hydroxides, 65
- Mumford, E. M., discovery of *Bacillus M.* 7 by, 13, 39–40
  - work of, on the mode of action of iron-depositing bacteria, 13
- Murray, J., and Renard, A. F., on the formation of glauconite, 74

- Newfoundland, pyrite in, 62
  - Wabana iron ore of, 50–51, 58, 60
- Nicolardot, M. P., work of, on ferric hydroxides, 66
- Nitrogen, conversion of, to soluble nitrates, 46
- *Nodofolium ferrugineum*, habit of, 11

Page.
Norway, Dunderland district, iron ore in 52
Nowo-Usensk, Russia, pyrite near 62

Ohio, ironstone and black-band ore deposits in 54–55
Organic iron solutions, precipitation of iron from, by bacteria 36–38, 67–68, 69
Organic matter, decaying, formation of hydrogen sulphide from 41
  decaying, reduction of iron compounds by 47
    sulphate-reducing bacteria present in 29
Oxidation of hydrogen sulphide by bacteria 44
Oxygen, precipitation of ferric hydroxide in absence of 33

Pennington mine, *Spirophyllum* in 26–27
Pennsylvania, ironstone and black-band ore deposits in 54–55
Physiology, general, of iron-depositing bacteria 11–13
  general, of sulphate-reducing bacteria 43–44
Pickering, S. W., work of, on basic ferric sulphate 67
Plates, cultivation of iron-depositing bacteria on 34–35, 38
Precipitation of iron by bacteria, experiments on 31–44
Proteus vulgaris, sulphate-reducing action of 30
Protein, decomposition of 46
  formation of hydrogen sulphide from 41, 83
Protozoa, deposition of ferric hydroxide by 11
Pseudomonas denitrifying action of 76
Pyrite, distribution of 60–62
  origin of 75
Pyrrhotite, origin of 74

Rammelsberg, Germany, pyrite at 61
Ransome, F. L., preface by 5
"Red mud," deposition of 54
Remains of bacteria, rapid perishing of 82
Renard, A. F., Murray, J., and, on the formation of glauconite 74
Reproduction of bacteria, methods of 8, 11, 21–22
Rocks, decay of, promoted by bacteria 46
Rowe mine, Cuyuna iron range, Minn., *Leptothrix* in springs at 17
  Cuyuna iron range, Minn., *Spirophyllum* in 26
Rubble ore, origin of 64
Ruff, O., work of, on ferric hydroxides 65–66
Russia, Nowo Usensk, pyrite near 62

Schorler, B., work of, on deposition of iron crusts in water pipes 23
Scum, ocherous, in iron spring, near Lake Kegonsa, Wis., phomicrographs of 17
Siderite, nature and origin of 54–57
  occurrence of, in Wabana iron ore 50
Siderocapsa treubii, activities of 29, 82
  habit of 9, 78
Silicates of iron, deposits of, nature and origin of 57–60
  precipitation of 73–74
  See also Glauconite, Greenalite, *etc.*
Sjögren, H., work of, on the precipitation of iron ores 70
Smith, N. R., Kellerman, K. F., and, work of, on the precipitation of calcium carbonate 76
Soils, bacteria in, precipitation of iron by 29–31, 32, 36–38
Spain, Huelva region, pyrite in 61
Spirillum desulfuricans, isolation of 42
  sulphate-reducing action of 30
Spirophyllum ferrugineum Ellis, activities of 77–78
  classification of 28–29
  cultivation of 27
  description of 27–28
  distribution of 80, 81
  habit of 10–11, 13
  occurrence of 17, 24–27
  photomicrograph of 22
  reproduction of 28
Spores, formation of, in bacteria 8
  See also Conidia.
Starch, decomposition of 45–46
Sterilization, effect of, in preventing precipitation 32, 37–38
  effect of, in preventing precipitation, plate showing 32
Styria, iron carbonate deposits in 57
Sulphate-reducing bacteria, activities of 29, 30–31, 41–44
Sulphates of iron, reduction of 82
Sulphides of iron, deposits of, nature and distribution of 60–64
  formation of, by chemical processes 74–75
Sulphur bacteria, activities of 44, 46, 83–84
  classification of 8, 9

Thiobacteria. *See* Sulphur bacteria.
Thiosulphates, reduction of, by bacteria 41–44
Thiothrix, activities of 44
Thuringite, composition and occurrence of 58, 60
Thwaites, F. T., acknowledgment to 8
Tomassi, D., work of, on ferric hydroxides 65
Trichobacteria, classification of 8–11
Troilite, occurrence of 74

Uglow, W. L., acknowledgment to 8
Underground occurrences of iron-depositing bacteria 25

Vacuum, precipitation of ferric hydroxide in 33
Van Bemmelen, J. M., work of, on ferric hydroxides 65
Van Delden, —, work of, on sulphate-reducing bacteria. 42
Van Hise, C. R., and Leith, C. K., work of, on the formation of iron silicates 73–74
Vaughan, T. W., on the precipitation of calcium carbonate 77
Vermillion Lake, Minn., ocherous scum from iron spring near, photomicrograph of 26
Vermilion ore district, Minn., *Spirophyllum* in 25–26
Vibrio hydrosulfureus, isolation of 42
  sulphate-reducing action of 30
Vitriol ocher, origin of 66

Wabana iron ore, nature and origin of 50–51
Water pipes, iron, deposition of ferric hydroxide in 23
Waters, natural, iron-depositing bacteria in 29–31
Weissowo salt sea, Russia, hydrogen sulphide in 83
West Virginia, ironstone and black-band ore deposits in 54–55
Westphalia, Prussia, pyrite in 61–62
Wheeler, A. D., acknowledgment to 8
Winogradsky, S., cultivation of *Leptothrix* by 18–19
  theory of, concerning iron depositing bacteria 11–12

Zopf, W., theory of, concerning iron depositing bacteria 11

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